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A STUDY OF INSTITUTIONAL SOLID WASTES

WEST VIRGINIA UNIVERSITY

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Improved systems and equipment for handling and disposing of solid wastes in multi-story buildings, especially institutions, are needed. This study was undertaken to analyze various aspects of the solid waste problem with a unit approach. Emphasis was placed on hospital wastes, which are a special source of disease dissemination to the public, because of their disease-organism content. The study was carried out at the West Virginia Medical Center over a 2-year period and was concerned with the quantities of generation and physical and chemical qualities of refuse produced at that time. Information from the study was coordinated with similar information obtained in other parts of the country to ascertain compatibility of data and broaden the data base. Bacteriological and virological studies are made. Safety precautions, costs, and recommended sampling procedures are given.

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FOREWORD

Man and his environemnt must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

In an attempt to solve the problems involved in solid waste disposal, this study investigated wastes generated by a public health institution. Emphasis was given to hospital wastes because of their disease organism content, which can be particularly harmful to man.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

PREFACE

NATURE AND SCOPE OF REPORT

The report herein presented is a compilation of several diverse but coordinated investigative efforts on various aspects of solid waste management in a teaching hospital (institution) made possible by a grant (EC 00265-02) to the Department of Civil Engineering, West Virginia University by the Solid Waste Management Office of the U. S. Environmental Protection Agency (formerly of the U. S. Public Health Service).

The research plan on which the grant was based called for a comprehensive investigation of all solid wastes generated by the teaching and hospital portions of the University Medical Center complex over a two-year study period. Studies of the quantities of refuse produced the physical, chemical, bacteriological, and virological characteristics of the wastes were undertaken. Safety considerations, handling costs, and future sampling procedures were spin-offs from this investigation. This is a final report of the efforts expended in this study of institutional solid wastes.

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I. INTRODUCTION

Need for Study

It is almost unbelievable that multi-million dollar buildings to serve specific purposes would be designed without proper consideration for the collection and disposal of the solid wastes being produced by the occupants of such buildings. Locally and nationally, there has been a lack of progress in developing improved systems and equipment for handling and disposing of solid wastes in multi-story buildings, especially institutions. Newly constructed buildings are in many cases still utilizing solid waste handling systems that were conceived decades ago, and it is not unusual to find rows of garbage cans lined up behind a multi-million dollar monumental building serving today's institutional needs.

Since a great number of institutions are somewhat repetitious in the solid waste which they produce, it appeared that a study could well be undertaken to make an analyses of various aspects of the solid waste problem based on a unit approach. Institutional facilities such as hospitals, school buildings, dormitories, and apartments fall under this general description.

Although tremendous progress has been made in the field of medicine with new methods and equipment being developed for the care and treatment of hospital patients, to date, very little progress has been made in developing new methods for disposing of solid waste from these institutions. The large quantities and wide diversities of solid wastes handled and disposed by health care facilities create a multitude of sanitation, economic, and administrative problems for these institutions.

The concentration of people having disease organisms places solid waste from hospitals as a potential source of disease dissemination to the public. Because of the dearth of reliable data on the characteristics and contamination potential of the wastes from medical care facilities, investigations were needed to properly characterize the types, quantities, and points of origin of refuse originating within health care facilities. With this information, hospital administrators, designers, public health officials would be in a better position to develop the necessary solutions in order to properly handle this problem. Recognizing that there are hospitals in every major community in the United States, acknowledging that most of these facilities already in existence have not provided solutions to existing problems, and observing the trend toward the increased use of single service or "disposable" items, a study of this nature was imperative.

Objectives of Study

As outlined in the proposal accepted by the Solid Waste Management Office for award of the grant to study the problems of institutional solid waste, the following specific aims are enumerated:

1. To determine the physical and chemical composition of the solid wastes from one medical school and hospital referral complex.
2. To determine whether bacteria and viruses are present in significant degrees and to do some isolation and identification.
3. To provide a classification basis and obtain quantity values for the wastes from the significant floors and departments.
4. To establish a safe procedure for studies on potential pathogenic wastes.
5. To provide information about solid wastes on a waste-producing unit basis that can be used by designers in establishing waste handling procedures and facilities for hospitals and other medical complexes.
6. To develop a sampling procedure that could be used in future solid waste studies including statistical analysis of the data to determine the percent errors and confidence in the sampling procedure.

In accomplishing these aims or objectives, reliable data on the character and quantity of refuse produced would provide a data base to which quantities expected in the future could be added. A reliable data base for each of the various wards, departments, and laboratories of such an institution, would allow progress to be made in overcoming the problems associated with waste management in such institutions.

Organization for Study

The overall project direction was provided by the principal investigator, Professor J. C. Burchinal, Department of Civil Engineering, West Virginia University who has been active in teaching and investigating sanitary engineering problems for many years. Cooperation with and by the administrative and operaional personnel of the Medical Center, imperative for successful undertaking of such a project, was obtained.

Physical analyses were made in the Civil Engineering Laboratory after collection and transport from the Medical Center. Chemical analyses were made in the engineering complex with assistance from the Chemical Engineering Department when needed. Virological studies were conducted by the Department of Microbiology under the direction of Dr. B. E. Kirk. Bacteriological studies were undertaken primarily in the Sanitary Engineering Labs of the Engineering Sciences Building. Cost studies were made by direct interrogation of hospital administrative personnel and examination of hospital documents. Statistical studies were made with the assistance of the Statistical Department under the direction of Dr. S. Wearden, with most analyses being run at the University Computer Center on the 360/75 IBM computer system. Project direction of control was maintained by Professor Burchinal and his staff, with assistance from Professor R. S. Zaltzman, and with extensive use of graduate students in conducting specific portions of the study. In addition, large numbers of students were employed as part-time collectors, sorters, grinders, and monitors of solid waste generation, production, handling, and disposal for the various portions of the study. The final report is a compilation of information obtained from individual dissertations, theses, and problem reports during the course of the two-year study period.

Nature and Scope of Study

While it would be beneficial to obtain information from many institutions, it was decided to limit this investigation to the West Virginia University Medical Center complex because of funds and distances involved. The study is primarily concerned with quantities and qualities of refuse being produced at the present time. This project did not try to obtain speculative information on expected quantities or changes in solid waste patterns in future years or in future institutions. It was felt that with a reliable data base, predictions on future quantities could be made as information becomes available.

Information from this study was coordinated with similar information obtained in other parts of the country to ascertain compatability of data and broaden the data base. The project was conducted over a two-year study period and with sufficient repetition to statistically validate results. Most previous studies have been limited in nature or restricted to total institutional waste output. Investigations in this project concentrated on quantities being produced at the unit level, which had never been done before with any statistical reliability.

While the main purpose of this study was to determine quantities and types of wastes produced from a Medical Center complex, it provided an opportunity to observe in detail the waste handling practices of such an institution and make recommendations for improving such procedures. This investigation was not envisioned as a panacea for all hospital solid waste problems, but rather as a necessary piece of data in the total plan to overcome current hospital problems.

II. DATA AND SAMPLE COLLECTION

Literature Survey and Problem Discussion

An extensive literature search was undertaken to determine what information was available on the problems of hospital solid wastes. Over 250 documents dealing with solid waste were reviewed. Many of these documents had been previously abstracted by Professor R. G. Bond and A. F. Iglar of the University of Minnesota School of Public Health. An annotated Bibliography of these documents is being prepared for publication.

Generally, the available literature concerned with solid waste disposal is written in a "popular" style, i.e. nontechnical and slanted toward the "layman". Since World War II, however, the literature has become somewhat more technical with studies being conducted on particular sanitation or contamination problems. Very little information was found on refuse composition and quantities, except in a general nature pertaining to waste produced by the entire institution. Most of the reports published, however, were estimates, and until recently, very little actual weighing and measuring of volumes and quantities has been accomplished.

The problems relating to infectious wastes produced in hospitals has been recognized for a considerable period of time. In 1908, Morse (1) wrote: "The need for a sanitary and convenient way for disposal of waste matter has always been recognized by those in charge of institutions devoted to the prevention and mitigation of human suffering." Morse elaborated on problems related to infectious waste produced in hospitals and cited records of waste handlers who contracted fatal diseases from exposure to infected matter. According to Morse, the first hospital waste incinerator was installed in 1891 at a New York hospital on West 17th Street. Prior to this, all burning of waste was practiced in hospital heating plants "to the detriment of the boilers." Lacking any acceptable disposal alternatives, public health authorities in the past, have insisted on incinerating hospital wastes because of their potential infectious nature. Consequently, incineration for sterilization and volume reduction is required by statute in a majority of U. S. communities.

Because a large portion of the wastes originating in a hospital complex comes from the preparation or scrapping of food its handling and disposal are important to proper waste management. According to Overton (2) much of this food waste has been sent to pig farms in the past. The balance of waste produced in a hospital, including the ash removed after incineration, has been deposited at private or city dumps and infrequently at sanitary landfills.

Four main factors have gradually brought about changes in methods of storing, handling, and disposing of the diversified types of solid wastes generated in medical care institutions:

1. Spread of infection
2. Safety of handling waste
3. Cost of labor
4. Use of single-service or disposable items

Literature written about hospital wastes has been directly or indirectly centered around one or more of these inter-related factors. Problems of safely handling solid wastes vary from the increased use of radioactive materials for patient care (3,4,5) to the use of discarded needles and syringes being picked up from waste disposal areas by drug addicts and children (6,7,8). Hospital waste collectors have been punctured by protruding needles from waste bags and sacks, or by placing arms or hands into the waste in order to compress it (9,10). Waste disposal activities have been singled out as one of the possible causes of increased hospital acquired infection (11,12). Not only is control of the spread of disease organisms important to patients and employees within the hospital, but it is also important to the population at large. Letourneau (13,14) has reported on potential infection from bandages, garbage, vomitus, casts, dressings, feces, and tools and/or equipment used to handle these wastes. Consequently, most hospitals have special procedures for handling wastes from contagious disease patients or from surgical or intensive care areas. Starkey (15,16) claims that handling of wastes is probably the largest factor in the transmission of infection, while Bond and Michaelson (15) concluded in their research project that waste did not disseminate significant amounts of bacterial contamination. Airborne contamination resulting from dumping wastes from one receptable to the other has been verified (18,19). The use of plastic liners in waste receptacles that can be closed and the liner removed without dumping contents, or the use of the paper sack container systems have resulted in a reduction in some of the problems associated with waste handling (20,21,22,23,24,25,26,27). These systems have also reduced labor costs due to the ease of handling refuse in this manner (28,29). Other labor saving devices used in hospitals and institutions include gravity chutes, grinders, pulpers, compactors, crushers, and balers to reduce volume, and in many cases, mechanically handle waste (30). These devices are not without problems however.

Recognizing that gravity chutes can reduce labor, many have been installed only to become fire hazards because cigarettes or burning materials have been dropped into them (31,32,33). Without proper air locks on door openings the chutes act as chimneys with air rising up and spreading contamination into surrounding corridors and patient areas (34,35,36,37,38). The spread of contamination occurs as refuse is dropped down from upper floors and the piston action of the wastes pushes the air out through inadequate doorways into surrounding corridors and patient areas.

Grinders have been used and are being used primarily to process food wastes, and some experiments have been conducted on grinding needles and syringes for discharge to the sewer and transportation to the sewage treatment facility (39,40,41). Grinders exist that are capable of handling most wastes produced in a hospital, but most sewage facilities throughout the United States are not capable of accepting such quantities and types of wastes.

Pulpers are being used in hospitals with reported savings in labor and space, (42,43,44) but only limited information is currently available. Compactors and crushers are finding increased usage for wastes other than infectious or wastes having excessive liquid content (45,46,47,48).

Incinerators still constitute the major waste reduction equipment used in hospitals, but increased air pollution control requirements make most existing hospital incinerators obsolete (49,50). Major renovations or the addition of pollution control equipment are usually required. Increased quantities of wastes are being imposed on already overloaded incinerators resulting in more pollution, including particles going up the stack not even burned. Consequently, poorly operated or overloaded facilities are not providing bacteriological sterilization of the waste, but may indeed be spreading air-borne contamination throughout the community (51,52). Incineration of increased quantities of synthetic materials mainly polyvinyl chloride, has resulted in high concentrations of chlorine gas which combines with water to form hydrochloric acid and cause extensive corrision in the incinerators and/or air pollution control devices (53,54).

Recent literature has shown that attempts to reduce the amount of manual labor for waste handling have resulted in the adoption of automatic or mechanical technique from industrial materials handling systems (55,56). Monorails (57), automatic elevators (58), automatic conveyors (59), central vacuum systems (60), pneumatic tubes (61,62,63) and on-floor incinerators (64) or crushers, are some of the newer techniques employed in modern hospitals (65,66,67).

Perhaps the most significant of the four main factors previously enumerated is the fourth, namely, the increased use of single-service or disposable items (68). Greater patient safety, more convenience, reduced labor resulting in increased economy are all claimed to result from the use of single-service items. While it is true that patient safety and reduction of disease spread are of prime importance in hospital operations, disposable items have not necessarily produced an overall economy to hospitals (69,70). Labor can be saved in departments formerly autoclaving or preparing articles for reuse but labor must be increased in departments that receive, store, distribute, collect and dispose of the single use items. Where disposables replace reusables, these changes have required larger storage areas, larger waste containers, more waste carts, increased incinerator loads, and increased waste handling (47,71,72,73,74,75,76,77). Costs that sometimes do not enter the budgets of smaller hospitals or community-owned hospitals include increased disposal costs. Where hospitals must pay for waste disposal, they are acutely aware of the increased costs disposables have wrought.

Many disposables do not relate directly to patient safety, but more to patient convenience. Everyone concerned with the use of these disposables should be fully aware of the load on disposable facilities both in and outside the hospital that are caused by these usages, especially in facilities designed years ago with grossly inadequate waste handling capacities. The overall environmental impact caused by decisions to use disposables also needs careful consideration especially in light of possible uses of complete plastic isolation rooms, operating rooms, disposable dishes and linens in general usage, plus types and uses of disposables not presently expected (78,79,80,81,82).

Few of the articles reviewed had specific information on the types and quantities of waste produced. Because of the tradition in hospitals to report most everything on a per patient basis, refuse generation figures have varied anywhere from 3 pounds per patient per day (83) to over 20 pounds per patient per day (84,68). As early as 1937 refuse generation was reported at 7 pounds per patient per day (2) and as late as 1965, 6 pounds per patient per day was still being reported (55), with others reporting at 8 pounds per patient per day (42,47). In 1966, however, it was reported a staggering 19 pounds per patient per day, including 8.3 pounds of garbage and 10.7 pounds of readily burnable materials (69). The unfortunate problem of reporting on a patient per day basis is that this method does not take into account the type of hospital or the type of service the patient is receiving and is therefore misleading. Consequently, attempts were made to report waste on a gross population basis which would include not only patients, but total number of doctors, nurses, maintenance, and administrative people employed at a hospital (85,61). Quantities of refuse produced on a per dapita basis also varied but over a smaller range. Since the patients are there 24 hours per day and most of the workers only on 8 hour shifts, an equivalent population was defined by taking into account those who would be on duty and patients during an equivalent 8 hour shift (85,61). In a comprehensive study conducted in Los Angeles (61) it was shown that when the amount of refuse produced from seven different hospitals was equated to the number of bed patients, values ranged from 3-1/2 pounds per bed patient per day to 16-1/2 pounds per bed patient per day. When the number of doctors, nurses, orderlies, janitors, volunteers, and out-patients, and other workers in the hospital was added to make an equivalent population based upon an 8 hour shift, values from the same seven hospitals ranged between 3 and 5-1/2 pounds per capita per day respectively. This approach seems logical since patients requiring extensive care and producing large quantities of waste usually require a larger number of attendants to take care of them and supply the materials. Thus, by taking into consideration more than just the patient, we have a more realistic approach to waste quantity generation. By using an equivalent population, hospitals serving different patient needs are more comparable in terms of refuse generation, and design criteria can be more meaningful for architects and hospital administrators. No studies were found in the literature pertaining to types and quantities of hospital wastes produced by each unit within the hospital. Since the location of various units of the hospital to sources of supply and disposal will significantly affect materials handling costs, it is imperative that this unit generation information be ascertained.

Specific literature as to the bacteriological or virological contamination of refuse was lacking, however, articles were found concerning virus contamination of bedding materials (86,87), and survival in waste water or sewage treatment facilities (88,89,90). The paucity of information relative to the specific aims of this project pointed out the need for reliable data to be obtained.

Facility Description

Medical Center

The health care institution used for this study was the West Virginia University Medical Center located in Morgantown, West Virginia. This modern, 438 bed, teaching hospital and research complex was built in 1960 and provides hospitalization, out-patient care, and specialized diagnostic, medical and surgical procedures on general and referral patients, as well as emergency care for the critically ill and accident victims. Complete teaching programs are conducted for the Schools of Medicine, Dentistry, Pharmacy, and Nursing, including clinical and post-graduate training, as well as in-service training for supportive personnel. In addition, the medical center actively supports many research efforts. This facility was studied because of its diversity of operations and because of its relationship to similar institutions throughout the country.

Physically, the entire medical center is in one large building but administratively and functionally it is divided into the Hospital section and the Basic Science or teaching section. Each section has separate staffs and schedules which made it easier to obtain refuse production data for each individual unit and still have meaningful information for the two major sections and for the entire complex. The hospital portion of the medical portion of the medical center has 11 floors including the basement and ground floors where most of the support services are located. The ninth (top) floor houses the air conditioning equipment. Floors 1 and 2 house clinics, X-ray, emergency rooms, admissions, records, and administration.

Floors 3 through 8 are primarily for inpatient care. In the Basic Sciences portion of the Center much of the ground floor is used as animal quarters. Floors 1 through 5 contain laboratories, class rooms and offices and are used primarily for teaching and research.

Various methods of solid wastes disposal and volume reduction are utilized within the Center. These include incineration, burial, selling, and discharge to the sanitary sewer. Three incinerators are used: a general purpose incinerator located on the basement floor of the Hospital, an animal incinerator located in the animal quarters section of Basic Sciences, and a human destructor located on the fourth floor of Basic Sciences. Radioactive wastes are disposed of by periodic burial; bone, meat, and grease wastes from food preparation are sold to a rendering firm, and most other food wastes are disposed of through garbage grinders into the municipal sanitary sewer system. Other wastes, plus incinerator ash, are placed in bulk storage containers, located at the loading dock, for mechanical collection by the University refuse disposal service. These wastes are then transported to the municipal landfill.

In the Hospital, a 24" diameter gravity refuse chute receives combustible waste and services all floors. This chute terminates in a room adjacent to the general purpose incinerator room. Needles, syringes, bottles, cans, and other noncombustible refuse are stored on each floor and are collected on carts for transport by elevator to the loading dock refuse storage containers. Waste from the Basic Sciences section is collected on carts for transport to either the general purpose incinerator or to the loading dock refuse storage containers.

The average daily bed occupancy at the Medical Center during the study period was 402 plus visits by an average of 496 out-patients per day. In the Hospital section these patients were served by an average daily staff of 1201 assisted by

142 volunteers and students. The staff consisted of: 483 doctors, administrators, and supervisors; 124 secretaries and clerks; 223 technicians, lab assistants, and food service personnel; 305 nurses, aids, and orderlies; and 66 housekeeping and maintenance personnel. (See Table A-1, A-2, Appendix A).

In the Basic Sciences section an average staff of 860 served 1069 students and provided research and support to the Hospital. The staff consisted of: 409 doctors, professors, and supervisors; 104 secretaries and clerks; 329 technicians, lab assistants, and shop personnel; and 18 maids and janitors. (See Table A-3, Appendix A).

All virological studies for this project were performed in the microbiological laboratories located on the second floor of the Basic Sciences section.

Engineering Laboratories

The University Engineering Sciences building houses laboratories used by the Civil Engineering Department which were made available during this study. A large laboratory in the sub-basement was used for sorting, weighing, and grinding the solid wastes collected and transported from the Medical Center. Sanitary Engineering laboratories on the basement and ground floor were used for physical, chemical, and bacteriological analysis. The description of specific tests performed and the equipment used are included in the respective chapters later in the report.

Administrative and clerical work was conducted in the Civil Engineering offices on the sixth floor and most data processing was handled at the computer terminal on the seventh floor.

Sampling Procedure

Based on the initial work conducted by E. G. Cleveland in 1968 (29), a comprehensive sampling program for the entire Medical Center was established. This consisted of dividing the wards and departments of the hospital and the Basic Sciences section into sampling stations that were easy to isolate and that contributed comparable amounts of refuse. Care was taken to include all waste from each nursing station and to keep this separate from other nursing stations. Waste from entire departments or laboratory functions was collected separately where possible. In this way it was possible to keep concurrent records on amounts of refuse produced and personnel generating it while not overloading the laboratory capabilities of the project. Table II-1 and Table II-2 list the sampling stations selected and show the frequency of sample collection. From these lists one can see the range of services provided by this institution.

Hospital Sampling Procedures

The entire quantity of refuse generated from each sampling station was collected during a 24 hour period on each day of the week, (but not during the same week.) Two full weeks were needed to sample each station one time or 14 weeks total to obtain this set of data. The sampling was conducted over an 18 month period. The standard procedure for collection was to station a man in front of a refuse chute and have him intercept all the refuse generated and place it into thirty gallon containers lined with a size 9, 3 mil polyethelene bags. When the container was full, the liner was tied shut and identified with a tag showing the date, time, and point of origin. The liner full of refuse was then removed from the container and stored nearby until picked up and transported to the laboratory for analysis. When loads contained heavy items such as glass, metal, plaster casts, or excessive moisture, additional liners were used to protect against breakage and possible spillage in either the hospital or laboratory. All refuse originating from contagious disease areas was handled separately and was delivered by hospital personnel in marked and sealed containers. Personnel conducting the study were required to wear white laboratory coats while on duty, and masks and gloves if handling potentially dangerous materials. At first, sample collectors remained on duty the entire 24 hour period but it was found that after 11:00 P.M. very little

Table II-1 Hospital stations and sampling frequency
(24 Hour Samples)

STATION	LOCATION	UNIT		FREQUENCY	
		Code	Function	Non-consecutive Days	Consecutive Days
83	8th Floor	META	Metabolic care	9	
82	"	PSYC	Psychiatric care	9	
72	7th Floor	GMED	General Medicine	9	
71	"	GMED	General Medicine	9	
62	6th Floor	PED	Pediatrics	9	
61	"	GYN	Gynecology, Neurology, Ears, Nose, and Throat	9	
52	5th Floor	SURG	General Surgery	9	
51	"	SURG	Surgery, Cardio Vascular Care, Urology, Eye, Chest, Burn Care	9	
40	4th Floor	OB	Maternity, New Born Care	9	
32	3rd Floor	ORTH	Orthopedics	9	
31	"	ORTH	Orthopedics, Neurosurgery	9	
36	"	OR	Operating Rooms	9	
37	"	IC	Intensive Care Unit, Recovery Rooms	9	
20	2nd Floor	2ND	Combined 2nd Floor Units	9	
21	"	XRAY	X-Ray Laboratories		5
22	"	BLAB	Blood Bank, Blood Laboratories		5
23	"	REG	Regional Medical Program		5
24	"	ENT	Ears, Nose, Throat Offices		5
25	"	CP	Cardio Pulmonary Laboratories		5
26	"	EMG	Electro Miliography Laboratories		5

Table II-1 (Continued)

STATION	LOCATION	UNIT Code	UNIT Function	FREQUENCY Non-consecutive Days	FREQUENCY Consecutive Days
11	1st Floor	ER	Emergency Rooms	9	
12	"	CLIN	Outpatient Clinics	9	
13	"	ADMN	Administrative Area	9	5
14	"	CAFE	Coffee Shop	9	
15	"	GIFT	Gift Shop	9	
G0	Ground Floor	GRND	Combined Ground Floor Units except Kitchen and Cafeteria	9	
G1	"	DIET	Dietary, Steno pool, Receiving		5
G2	"	KITN	Kitchen, Cafeteria	7	
B0	Basement Floor	BSMT	Combined Basement Floor Units	9	
B1	"	PHCY	Pharmacy		5
B2	"	LAUN	Laundry		5
B3	"	CENT	Central Supply		5
B4	"	COBT	Radiation Therapy, Cobalt		5
B5	"	ALFD	U. S. Public Health Service Appalachian Health Laboratories		5

		Consecutive and Non-Consecutive days
Ground Floor	Loading Dock	43
Basement Floor	Incinerator Room	43
Loading Area	Refuse Truck	92

Table II-2 Basic Sciences stations and sampling frequency
(24 Hour Samples)

STATION	LOCATION	UNIT	FREQUENCY CONSECUTIVE DAYS	NON CONSECUTIVE DAYS
41	4th Floor	Offices	5	5
42	"	Laboratories	5	5
31	3rd Floor	Offices	5	5
32	"	Laboratories	5	5
21	2nd Floor	Offices	5	5
22	"	Laboratories	5	5
23	"	Library	5	5
11	1st Floor	Offices	5	5
12	"	Laboratories	5	5
G1	Ground Floor	Offices	5	5
G2	"	Laboratories	5	5
G3	"	Animal Quarters	5	5
G4	"	Repair Shops	5	5
G5	"	Cafeteria	5	5
			Consecutive and Non Consecutive	
Hospital Incinerator Room		Basement	43	
Hospital Loading Dock		Ground Floor	43	

waste was generated. For the remainder of the study, the chute was taped shut from 11:30 P.M. to 7:00 A.M. the following morning and a sign was placed on the door asking that refuse be placed in containers provided. There was excellent cooperation by the hospital staff in doing this. The refuse collected at night was tied up and labeled by a sample collector at 7:00 A.M. before he moved to a new sampling station. Collectors worked in convenient but continuous shifts from 7:00 A.M. to 11:30 P.M. during the study period.

Bagged and tagged refuse was picked up from the hospital at least twice daily and transported 1.7 miles to the Engineering Building where laboratory facilities were available. The Civil Engineering International Travelall was used for most of the transportation with private cars used only when no other vehicle was available.

Refuse from food preparation and dishwashing areas was not collected for laboratory analysis. It was felt that this refuse had little pathogenic contamination and was similar to other hospital food preparation refuse. Refuse produced from food preparation and food scrapping operations was weighed and measured prior to its discharge into food grinders, sewer, or storage containers. Food waste from isolation patients was collected in paper sacks, sealed and weighed without separating prior to disposal.

In addition to the series of samples collected for laboratory analysis, each station was sampled for weight and volume of refuse produced concurrently with the quantity of refuse produced by the entire hospital. To obtain additional information, generation from several sampling stations was analyzed by measuring weights and volumes from individual rooms or offices during a consecutive 5 day period. This required 4 weeks to accomplish.

Total weights and volumes reaching the incinerator room were measured for at least 43 separate 24 hour periods using a Fairbanks Morse and Company 1000 lb. capacity platform scale. Total weights and volumes reaching the refuse storage area at the loading dock were measured prior to placement in bulk storage containers. Weights from at least 43 separate 24 hour periods were recorded using a model 2430 Howe Scale Company platform scale. In addition, the refuse collection truck was weighed 92 times before and after pickup, by using two Type-A Hi-Way Load-Ometer 20,000 lb. portable truck scales borrowed from the West Virginia Department of Highways.

Weights of soiled linen reaching the laundry were recorded each day by laundry personnel. An average of 7,830 pounds of linen were processed each day during 1968 and 1969. Data for specific study periods and monthly for the years of 1968, 1969 are shown in Table A-6 Appendix A.

Basic Sciences Sampling Procedures

Total refuse generated for a 24 hour period was collected from each of the Basic Sciences sampling stations on each of five days (Monday through Friday) of separate weeks. In addition, weights and volumes originating in each room or laboratory were measured for a 24 hour period on each of five consecutive days. One week was needed to sample each station once or 10 weeks total for the collection of these samples. This sampling was carried out over an 18 month period to include possible seasonal variation.

The standard procedure for collecting samples was for a sample collector to accompany each custodian as he made his rounds and intercept waste by placing it in size 9, 3 mil thick polyethelene bags. When full, bags were tied shut and identified with a tag showing date and point of origin. Bags were then collected and transported to the Engineering laboratories for analysis. Extra liners were used for samples containing large quantities of glass, wood, metal, or other heavy objects to prevent spillage of refuse.

During the time that quantities were not retained for laboratory analysis, sample collectors weighed the refuse in a plastic container suspended from a Model 8910 Hanson portable spring scale. Volume of refuse was determined by its level in the container and then the refuse was emptied into carts for transportation to either the incinerator or refuse storage area.

Refuse generated from the student cafeteria was handled similarly to that from the hospital food preparation area. It was intercepted, weighed and measured and then allowed to follow its usual course for disposal.

Waste from the animal quarters was not handled by the study personnel but was handled by animal quarter personnel. The number and weights of animals incinerated and amounts of ash removed were weighed, measured, and recorded for the project by these personnel.

Anatomy wastes, autopsy wastes, and surgical wastes such as amputations and organs removed, were auto-claved and then weighed and placed in a special "Human Destructor" incinerator for disposal. Ash from this operation was weighed and recorded for the project by the mortician in charge. Project sample collectors did not handle this type of waste.

Initial Sample Preparation

Laboratory personnel in the Engineering laboratories were required to wear laboratory coats, surgical face masks, and rubber gloves while sorting, weighing or grinding. Laboratory personnel were urged to shower immediately after working. The laboratory coats were commercially laundered, and the laboratory was cleaned after each day's sorting and sanitary conditions were observed.

New brown paper from a 54" wide roll was placed on the sorting table at the beginning of each day's work or as often as needed to maintain clean conditions. Bags of refuse were weighed on a Howe Richardson Model 54 XL platform scale and the emptied onto the table for sorting into plastic bins in the categories shown on Table IV-6.

After sorting, totals of each category were weighed on a Pennyslvania Scale Company Model I-10 table scale and recorded. The sum of the categories was then checked against the original sample weight as a precaution. One twentieth (5 percent) by weight of each grindable category (all categories except glass, metal, wood, rubber, and hard plastic) was recombined in a plastic bag, tagged and saved for further processing. Exclusion of certain categories of waste was partly due to laboratory restrictions, lack of grinding capability during the initial phase of the laboratory work and sample size necessary for the different chemical and biological tests. The remainder of the refuse was placed in a large plastic container and hauled to the refuse storage area for mechanical pickup by the university packer truck. A 2-1/2 cubic yard Truxmore metal bulk container was purchased and placed at the Engineering Sciences Building to handle the increased waste load caused by this investigation.

The grindable portions saved were then processed thru a "Davis-Built" granulator machine to reduce the size of sample particles to less than 1 inch. A special burlap filter was designed and employed to retain the processed particles. The sample was then fine ground through a Standard Model 3 Wiley Mill to pass a 2 mm sieve. The effluent from the mill was thoroughly mixed and approximately 100 gms retained in a 24 oz. deep-form seamless closed tin box for chemical and physical analysis. The boxes were labeled as to date and origin of the sample. Duplicate samples were retained when possible.

III. SOLID WASTE GENERATION BY MEDICAL CENTER AND INDIVIDUAL UNITS

Introduction

One of the main objectives of this study was to determine waste generation rates for the various units of a medical care institution. This information was lacking but through this study effort, data is now available to assist architects, designers, administrators and others who need to know types, quantities and sources of waste generation. Since waste handling is basically a materials handling problem, generation information is necessary to adequately design materials flow systems, especially with ever increasing quantities of single use items in health care facilities.

An analysis of total waste production from the two major sections of this institution precedes the analysis of waste generation by hospital units in this chapter. All of the data is presented in pounds. Classification of the waste components, volumes, and densities are subjects handled in a subsequent chapter.

Statistical Procedures

Information obtained during the data gathering operations for use in determining waste generation was punched onto IBM data cards for ease of analysis and manipulation on the University's IBM 360/75 computer. Means, standard error of the mean, 95 percent confidence intervals and sample totals were computed and listed for most of the results.

The use of the computer allowed analysis of data to be performed that would have been extremely laborius and time consuming if done manually.

A special stepwise regression analysis, DMD OZR BIOMED, on file at West Virginia University's Computer Center was used to help determine the best variables for the prediction equations.

Programming and statistical assistance was provided by personnel of the University's Department of Statistical and Computer Science.

Results and Discussion

Total Wastes Generated

The total daily generation of solid wastes from the West Virginia University Medical Center was determined from measurements taken over a two year study period. For this, three sets of separate data were compared. One set consisted of data generated during seven consecutive days, another set was made up from each of seven weekdays from different weeks, and the third consisted of totals of eight different weeks, each made up of seven consecutive days. Total quantities for the first two sets of data were obtained by adding the amounts of waste generated by individual sources (units described on Table III-1 and Table III-2 and totaled for Hospital and Basic Sciences portions of the Medical Center. The third study included only wastes reaching the general purpose incinerator and the loading dock.

The summarized results of this study are shown on Table III-1 where the data are given under headings representing the two main generation sources, the Hospital and Basic Sciences. For comparative purposes, this table includes the high daily value observed in each study and a theoretical high, equal to the sum of all high values for each unit. These nigh values can be used for determining total expected loads.

Comparing values of means obtained for the three separate studies shows a maximum difference of 256 pounds (or 7 percent between means) for the Hospital, 181 pounds (or 12 percent) for the Basic Sciences and 437 pounds (or 9 percent) for the total Medical Center complex. Thus, as a whole the data obtained were consistent and can be considered reliable for the different set of conditions observed.

Table III-1 Daily solid waste generation totals

UNIT	STUDY 1 CONSECUTIVE DAYS	STUDY 2 NON-CONSECUTIVE DAYS	STUDY 3 INCINERATOR AND LOADING DOCK	TO LOADING DOCK ONLY	TO INCINERATOR ONLY
HOSPITAL					
Mean	3475.2	3228.0	3219.1	1290.8	1928.3
High	3863.4	3863.4	4033.0	1614.9	2418.1
Theoretical High*	4567.9	4567.9	4915.0	2095.0	2820.0
B. S. B.					
Mean	1475.0	1389.8	1294.4	763.2	531.2
High	1595.3	1440.9	1554.6	919.2	635.4
Theoretical High*	1850.6	1804.6	2609.0	1682.0	927.0
TOTALS					
Mean	4950.2	4617.8	4513.5	2054.0	2459.5
High	5458.7	5304.3	5587.6	2534.1	3053.5
Theoretical High*	6418.5	6372.5	7524.0	3777.0	3747.0

* Theoretical High = Sum of all Individual Unit Highs

Table III-2 Comparison of solid waste generation rates

	HOSPITAL ONLY	MEDICAL CENTER	LOS ANGELES STUDY (32)***	
			LOW VALUE	HIGH VALUE
Bed Patients	402	402	144	2018
Disposable Wastes	3,300 lbs.	4,700 lbs.	732 lbs.	23,200 lbs.
lbs./Bed Patient	8.2	11.7	3.6	16.7
lbs./Person - Gross Pop.*	1.6	1.1	0.9	1.8
lbs./Capita - Equiv.Pop.**	4.0	3.6	3.1	5.6
Reusable Wastes	9,630 lbs.	10,140 lbs.	1,720 lbs.	54,500 lbs.
lbs./Bed Patient	24.0	25.2	11.9	29.6
lbs./Person - Gross Pop.*	4.5	2.4	2.6	4.1
lbs./Capita - Equiv.Pop.**	11.7	7.8	8.1	10.2
Total Wastes	12,930 lbs.	14,840 lbs.	2,452 lbs.	77,700 lbs.
lbs./Bed Patient	32.1	36.9	17.0	46.3
lbs./Person - Gross Pop.*	6.1	3.6	3.7	5.4
lbs./Capita - Equiv.Pop.**	15.7	11.4	11.3	15.3

* Sum of all patients, outpatients, paid staff, doctors and volunteers

** An average 8 hour population census counting the number of outpatients at one half

*** Low and high values from a study of seven hospitals

It should be noted that figures in Table III-1 include only wastes which require disposal. Other wastes studied but not included in this table are wastes that are reusable and are normally recycled, such as soiled linen, (see Table A-6, Appendix A) dinnerware and patient care items.

To further test the validity of data reported in Table III-1, waste production or generation rates were calculated and compared to data obtained from a study of seven hospitals in Los Angeles, California (61) ranging from a bed patient occupancy of 144 to an occupancy of 2,018. Wastes are compared in three categories: disposable, reusable and total. Refuse production rates based on number of bed patients, total or gross hospital population and equivalent population are recorded for all three categories on Table III-2. Calculations and data used to obtain these figures are recorded on Table A-4, Appendix A.

A comparison of data shows that values obtained in this study are in agreement and within the ranges recorded for the Los Angeles study. The figure of 8.2 pounds of disposable waste per bed patient per day for the Hospital and 11.7 pounds per day for the total Medical Center are also in agreement with most reports reviewed.

It is important to note that the Los Angeles study contained two teaching hospitals where their reported populations included students, teachers, researchers and supporting personnel comparable to the population of this institution. Thus, the validity of the comparison is further enhanced and results could, therefore, be considered as typical or expected from institutions of this nature.

It is interesting to note variation between different rates of waste production, and within each particular rate. When reporting rates based on a bed patient basis, values ranged from 3.6 to 16.7 pounds per patient for disposable wastes in the Los Angeles study. This institution had a value of 11.7 pounds but other studies reported rates as high as 19 to 20 pounds per patient (68,69,81,84).

When using the very same quantities of waste from the same hospitals to calculate rates based on the institution's total or gross population, values ranged from 0.9 to 1.8 pounds per capita in the Los Angeles study and were calculated to be 1.1 pounds per capita in this study. While variation between the different rates is due largely to the method of reporting, variation within any particular rate is due mostly to the inability of that method to reflect differences in the type or amount of care given to each patient at the various institutions studied. With this great amount of unpredictable variability, these two methods of reporting waste generation are very unreliable for design purposes. Rates reported on these two bases are confusing, misleading and should not be used.

In order to overcome differences in reporting waste rates and to equate institutions giving different types and amounts of care, the American Public Health Association study (85) and the Los Angeles County study (61) proposed that wastes should be calculated in terms of an "equivalent population." This "equivalent population" is defined by the Los Angeles study as the average 8 hour population census over a seven day week, counting the outpatients at one half value. In addition to patients, this method includes staff and others who are contributing to the daily wastes but are not considered when reporting on a per patient basis. This method is also different from gross populations in that patients who are present 24 hours a day are valued at more than someone there for a part of the 24 hour period. The total number present during the 24 hour period is averaged into an 8 hour shift, which is then used to calculate the daily waste production rate.

Following this definition, the rates calculated are also reported in Table III-2. In the Los Angeles study, these rates vary from 3.1 to 5.6 pounds per capita for disposable wastes and have a calculated mean value of 3.8 pounds per capita. The value of 3.6 pounds per capita obtained for this Medical Center is very close to the Los Angeles study mean. Equivalent populations rates for total wastes vary from 11.3 to 15.3 pounds per capita in the Los Angeles study, but if these same quantities of wastes are used to calculate rates on a bed patient basis, they vary from 17.0 to 46.3 pounds per patient.

This equivalent population method for computing total waste generation appears to be more reliable than any other method so far devised. Use of this method should enable designers to anticipate total quantities of refuse from various types of institutions from calculations based on the equivalent population of that institution. This will help determine total quantities from an entire institution; however, prior to this study, no one has developed generation equations for the individual units of an institution.

Unit Wastes Generated

Based on the hypothesis that different types of patient care units would produce different quantities and possibly different characteristics of wastes, each unit of the Hospital and Basic Sciences was sampled individually. Tables III-1 and III-2 list the units, type of activity performed in each unit and frequency of sample collection. Each unit represents a particular type of patient care or particular nursing station, with basically similar care being given to patients within any unit.

The mean daily weight, high day's weight, standard error of the mean and 95 percent confidence interval for each unit are listed on Table III-3 for the Hospital and on Table III-5 for the Basic Sciences. Values for supplemental studies that were conducted to provide additional information are listed on Table III-4 and Table III-6 for Hospital and Basic Sciences respectively.

Table III-3 Solid waste generation by hospital units
(initial study)

SAMPLING STATION	UNIT	MEAN DAILY WEIGHT*	HIGH DAY'S WEIGHT*	STANDARD ERROR OF MEAN	95% CONFIDENCE INTERVAL LOW WEIGHT*	HIGH WEIGHT*
83	Metabolic	24.6	39.4	3.7	15.4	33.8
82	Psychiatric	27.1	34.8	3.0	19.8	34.3
8th Floor		51.7	73.2	4.9	39.6	63.8
72	General Medicine	88.9	107.9	5.0	76.6	101.2
71	General Medicine	76.9	115.0	10.8	50.4	103.4
7th Floor		165.8	222.9	13.6	132.7	199.0
62	Pediatrics	95.8	181.6	14.9	59.2	132.3
61	Gynacology	80.0	150.2	13.4	47.3	112.8
6th Floor		175.8	231.8	23.0	119.5	232.1
52	Surgical	193.2	288.1	22.5	138.1	248.2
51	Surgical	167.8	310.3	26.3	103.5	232.1
5th Floor		361.0	598.4	40.9	260.8	1461.1
40	Maternity (4th Floor)	96.4	133.7	8.0	76.8	115.9
32	Orthopedics	69.5	96.0	6.6	53.3	85.6
31	Orthopedics	91.2	122.9	10.2	66.3	116.2
36	Operating Rooms	191.3	260.3	31.5	127.4	255.2
37	Intensive Care	103.3	140.3	13.0	71.5	135.1
3rd Floor		455.3	619.5	44.7	294.2	512.8
2nd Floor		34[illegible]	388.3	[illegible]5.8	297.8	385.6

* All weight in pounds

Table III-3 (continued)

SAMPLING STATION	UNIT	MEAN DAILY WEIGHT*	HIGH DAY'S WEIGHT*	STANDARD ERROR OF MEAN	95% CONFIDENCE INTERVAL LOW WEIGHT*	95% CONFIDENCE INTERVAL HIGH WEIGHT*
11	Emergency Rooms	30.8	44.7	3.7	21.7	39.9
12	Operating Clinics	66.4	81.4	8.1	43.9	88.9
13	Administration	65.3	109.0	12.8	33.9	96.6
14	Coffee Shop	24.7	30.0	1.8	20.4	29.0
15	Gift Shop	13.3	35.0	3.8	4.1	22.5
1st Floor		200.5	300.1	25.7	116.2	246.8
G0	Dietary Receiving	168.3	197.0	13.2	131.7	204.9
G2	Kitchen - Cafeteria	1309.0	1515.0	75.2	1122.4	1495.6
Ground Floor		1477.3	1712.0	97.6	1200.7	1678.3
Basement Floor		149.7	187.0	15.1	105.1	194.3
Column Totals		3475.2	4567.9	- -	2686.6	4363.4
Statistical Totals		3228.0	3863.4	294.2	2508.2	3947.9

* All weight in pounds

Table III-4 Solid waste generation by hospital units (supplemental study)

SAMPLING STATION	UNIT	MEAN DAILY WEIGHT*	HIGH DAY'S WEIGHT*	STANDARD ERROR OF MEAN	95% CONFIDENCE INTERVAL LOW WEIGHT*		95% CONFIDENCE INTERVAL HIGH WEIGHT*
21	X-ray	77.0	110.0	3.8	52.8	-	101.4
22	Blood Analysis	231.1	254.5	9.8	203.9	-	258.3
23	Regional Medical	11.1	12.0	0.4	9.9	-	12.3
24	Ears,Nose,Throat	8.8	13.0	1.7	4.0	-	13.6
25	Cardio-Pulmonary	33.6	42.0	2.4	26.9	-	40.3
26	EMG	1.7	3.0	0.4	1.0	-	2.8
Total 2nd Floor		363.3	434.5	18.4	312.3	-	414.3
13	Administrative Area	75.7	88.0	7.6	54.5	-	96.9
G0	Ground Floor	24.6	32.0	4.2	12.7	-	36.5
G1	Dietary	15.7	24.5	2.6	8.5	-	22.9
Total Ground		40.3	54.5	2.2	34.2	-	46.4
B1	Pharmacy	30.4	38.7	3.0	21.9	-	38.8
B2	Laundry	41.7	82.9	11.7	9.1	-	74.3
B3	Central Supply	98.3	127.2	11.7	65.7	-	130.8
B4	Radiation Therapy	5.1	9.5	1.1	2.0	-	8.2
B5	Appalachian Health Laboratory	15.8	37.0	5.8	1.0	-	31.9
Total Basement		191.2	251.4	19.3	137.7	-	244.8

* All weight in pounds

Table III-5 Solid waste generation by Basic Sciences units (initial study)

SAMPLING STATION	UNIT	MEAN DAILY WEIGHT*	HIGH DAY'S WEIGHT*	STANDARD ERROR OF MEAN	95% CONFIDENCE INTERVAL LOW WEIGHT*	HIGH WEIGHT*
41	Offices	83.3	124.8	12.9	47.4	119.2
42	Laboratories	64.5	96.0	8.5	40.8	88.2
4th Floor		147.8	220.8	14.1	108.6	187.1
31	Offices	56.3	75.0	6.7	37.7	74.9
32	Laboratories	62.9	100.3	14.2	23.3	102.4
3rd Floor		119.2	175.3	17.5	70.7	167.7
21	Offices	44.5	74.4	9.6	17.9	71.1
22	Laboratories	122.8	137.0	6.5	104.7	140.8
23	Library	16.7	19.8	1.4	12.8	20.5
2nd Floor		184.0	231.2	15.2	141.8	226.1
11	Offices	59.9	81.0	10.4	31.0	88.9
12	Laboratories	161.0	219.8	17.4	112.8	209.1
1st Floor		220.9	300.8	12.3	186.7	255.2
G1	Offices	69.9	114.8	16.2	24.9	115.1
G2	Laboratories	59.7	95.3	13.6	22.0	97.3
G3	Animal Quarters	304.2	336.8	15.0	259.9	348.5
G4	Repair Shops	11.6	24.6	3.4	2.1	21.1
G5	Cafeteria	272.4	305.0	12.7	237.1	307.7
Ground Floor		717.8	876.5	19.0	664.9	770.7
Column Totals		1389.7	1804.6	--	974.4	1804.8
Statistical Totals		1389.8	1440.9	32.3	1300.1	1479.5

* All weight in pounds

Table III-6 Solid waste generation by Basic Sciences units (supplemental study)

SAMPLING STATION	UNIT	MEAN DAILY WEIGHT*	HIGH DAY'S WEIGHT*	STANDARD ERROR OF MEAN	95% CONFIDENCE INTERVAL LOW WEIGHT*	HIGH WEIGHT*
41	Offices	82.2	89.0	2.5	75.1	89.3
42	Laboratories	94.4	144.0	17.9	44.6	144.2
4th Floor Totals		176.6	233.0	20.5	119.8	223.4
31	Offices	34.8	44.5	2.6	32.6	44.2
32	Laboratories	67.1	95.5	8.2	44.2	90.0
3rd Floor Totals		105.5	140.0	10.1	77.5	133.5
21	Offices	62.3	91.5	8.5	38.6	85.9
22	Laboratories	45.0	51.0	2.4	38.5	51.5
23	Library	16.7	19.8	1.4	12.8	20.5 * *
2nd Floor Totals		124.0	162.3	8.9	99.4	148.5
11	Offices	94.3	107.5	3.8	83.7	104.9
12	Laboratories	201.4	226.5	8.0	179.1	223.7
1st Floor Totals		295.7	334.0	10.2	267.5	323.9
G1	Offices	65.9	119.5	16.0	21.4	110.4
G2	Laboratories	107.3	173.5	18.0	57.4	157.1
G3	Animal Quarters	304.2	336.8	16.0	259.9	348.5 * *
G4	Repair Shops	23.9	46.5	8.5	1.0	47.6
G5	Cafeteria	272.4	305.0	12.7	237.1	307.7 * *
Ground Floor Totals		773.7	981.3	8.3	750.8	797.0
Column Totals		1475.1	1850.6	- -	1126.0	1824.7
Statistical Totals		1475.0	1595.3	35.7	1375.8	1574.2

* All weight in pounds

* * Values from initial study

In this institution, patient care units are located on floors three to eight inclusive; outpatient units (clinics) and emergency rooms are located on the first floor, and support units (all others) are located from basement to second floor. Patient care units contributed 37.6 percent, outpatient units and emergency rooms combined contributed 2.8 percent and the support units contributed 59.6 perdent of the mean daily weight. It is significant to note from these data that the hospital kitchen, cafeteria and coffee shop combined contributed 38.4 percent of the mean daily hospital weight or an amount exceeding that of the combined patient care areas. This waste from the kitchen includes all of disposable material produced there including single use dinnerware used for meal service to all isolation patients. Meals were served to all other patients on china service during the period of study. The proportion of wastes produced by all food service and food preparation units of the entire Medical Center accounted for 33 percent of the total combined weight, however.

Although outpatient care areas contributed a relatively small portion of wastes generated when measured by individual units, it should be noted that in this particular institution, outpatient care units generate 15 percent of clinical laboratory work, 42 percent of X-ray examinations and an unaccountable amount of administrative work. Wastes from these additional activities are included in support unit totals.

The remaining portion of the Medical Center was studied in terms of both activity and Personnel classifications in order to better understand the waste generation processes. Table III-7 lists personnel classifications and room use categories used in this study. Tables A-1, A-2 and A-3 in Appendix A list the population census for each personnel classification for both Hospital and Basic Sciences units.

Table III-7 Personnel classifications and room use categories

CLASSIFICATION	PERSONNEL INCLUDED
1.	Patients, outpatients
2.	Doctors, administrators, directors supervisors, dentists, chiefs
3.	Secretaries, clerks, cashiers, office support personnel
4.	Laboratory assistants, technicians, graduate assistants, maintenance men, laborers
5.	Registered nurses, licensed practical nurses, practical nurses, nurse's aids, orderlies
6.	Janitors, maids, housekeepers, floor sweepers
7.	Volunteers, students

CATEGORY	ROOM USE
A.	Offices, nursing station headquarters
B.	Laboratories, work areas, shops
C.	Restrooms, locker rooms, dressing rooms
D.	Classrooms, conference rooms, libraries
E.	Supply rooms, storage areas
F.	Lounge areas, waiting areas
G.	Patient care rooms, examination rooms

Using this system, a laboratory technician in a laboratory would appear under the same heading as a mechanic in a repair shop but the room use category would be different. A doctor in a patient care area would be different from a doctor shown in an office where his main function might be related to paperwork. Doctors, administrators, supervisors, directors and dentists were put together in the same classification because it was felt that in an office they would most likely produce about the same amount of waste, while in another room category their function might be different. This provided a good basis for determining room usage within a unit or between units. Since each unit was studied separately, there was no conflict between categories or classifications.

The first step towards obtaining a relationship between the quantity of waste produced and the people who produced it was to divide the amount of waste per unit by the number of patients per unit. The values obtained varied considerably not only within units but between units as well. The gross population was then used as a divisor to obtain weight per capita per day. As with values for total generation, these unit values varied widely. Next, the equivalent population for each unit was computed and divided into the amount of waste produced per unit but still no meaningful equations were produced. The equivalent population method that worked so well for total waste quantities from the entire institution did not work well for individual units. This is due, perhaps, to the fact that for the entire institution, all of the wastes from patient care and support activities are combined, as are population totals. On a unit basis, however, wastes come only from one particular unit and support activities are not included. Thus on a unit basis, there is no overlapping or compensation to provide a balance. These calculated values are listed in Table A-5, Appendix A.

Quantities of waste produced per unit per day were then correlated against numbers of people in each classification or in combinations of classifications for that day to see if there were any meaningful relationships. The weight was held as the dependent variable and the numbers in each classification, their squares, square roots, cubes, cube roots and combinations of various classifications were used as independent variables in a stepwise regression analysis that selected the best of the independent variables and calculated prediction equations using these variables. Means, standard deviations, analysis of variance, F ratios, R values, R squared values, predicted weights and residuals were computed by the University Computer Center for all units studied.

Each unit study produced its own best prediction equation based on the independent variables selected by statistical analysis. It was felt that a coefficient times the cube root of the number of nurses plus another coefficient times the square of the number of housekeepers for example, would not be a practical equation for any general use. The number and type of independent variable was then restricted to whole numbers or combinations of whole numbers in an attempt to obtain an equation of only one best variable that would be easy to apply and yet still be reliable. As expected, each unit had a different coefficient for every independent variable selected in the analysis. For a designer to use a different coefficient or equation for each unit did not seem very practical, especially with no other data from other institutions to verify the values. It was observed that certain patient care areas had coefficients that were similar in quantity and tended to group themselves into two main divisions. Each division was composed of units giving approximately the same type of care. Patient care units such as the operating rooms, intensive care area, maternity and newborn infant care, surgical care and orthopedic care all produced heavy quantities of waste and had large staffs. Patient care units such as metabolic research, psychiatric care, general medicine, pediatric care, gynecology, ear-nose-and-throat, and neurology all produced lighter amounts of waste and had smaller staffs. The data for units in each division were then pooled and analyzed to find the best overall correlation and corresponding prediction coefficient and equation. Fortunately the same independent variable turned out to be best in each division but with a new coefficient. The best independent variable found for each division was a summation of the total paid staff for a 24 hour period minus the number of doctors. This variable did not include the number of patients nor the number of non-paid volunteers or students. To determine why the doctors and volunteers were excluded, the data were further analyzed. It was observed that the number of doctors varied considerably for the same unit on different days as did the number of students and volunteers. Doctors were also counted at more than one unit as they made their rounds. This would not appear when calculating the equivalent population from the entire hospital but would show up on a unit basis. The paid staff of nurses, aids, clerks, orderlies, housekeepers, and maids of a unit remained more constant and paralleled the amount of waste produced. This is probably why the best variable included only paid staff minus all of the doctors. Values for coefficients, prediction equations, R square and standard errors obtained from the analysis are listed in Table III-8.

When support activities were analyzed it was found that units dealing mostly in paper work produced similar quantities of waste, while waste from other support activities, such as the kitchen-cafeteria, was better equated to the number of meals served than to the staff or combinations of staff classifications. The best independent variable for all support activities, except certain special ones, turned out to be the number of paid staff minus the number of supervisors or administrators (sum of classifications 3 through 6) times a coefficient. These values are also shown on Table III-8.

It should be noted that these coefficients and equations will estimate average daily solid waste quantities. An upset, extra patients, special treatment requirements

Table III-8 Solid waste generation equations

UNITS	COEFFICIENT	EQUATION	R^2	STANDARD ERROR
Light Care Units				
Metabolic, Psychiatric, General Medicine Pediatrics, Gynecology, Neurology, Ears-Nose-Throat	2.77	2.77(s)=lbs. waste/day	.92	0.127
Heavy Care Units				
General Surgery, Neurosurgery, Cardiovascular, Urology, Eye, Chest, Burn, Patients, Maternity, New Born, Orthopedics, Operating Rooms, Intensive Care, Recovery	4.47	4.47(s)=lbs. waste/day	.89	0.231
Support Units				
Administrative Offices, Gift Shop, Dietary Offices, Laundry, Pharmacy, Receiving, Regional Medical Program, Appalachian Respiratory Diseases Lab.	2.21	2.21(s)=lbs. waste/day	.89	0.134
Special Units				
X-Ray, Radiation Therapy, Emergency Room, Central Supply	0.48	0.48(n)=lbs. waste/day	.68	0.079
Clinical Laboratories, Out Patient Clinic	0.19	0.19(n)=lbs. waste/day	.71	0.035
Kitchen, Cafeteria	1.5	1.5(n)=lbs. waste/day	.76	0.173

(s) = Sum of the paid staff during a 24-hour period, not including doctors (categories 3-6)

(n) = Number of patients treated, order baskets filled, tests run or patient meals served or any number of unexpected occurrences may cause waste quantities to fluctuate above and below estimated daily values. Anticipated increases in the use of disposable items may necessitate increasing the value of coefficients sufficiently to accommodate the additional weight and volume. For example, disposable sheets weigh about 25 percent of the weight of linen sheets. If a total conversion to throw-away linen were undertaken at the institution studied, the increased weight would be approximately2,000 pounds per day. That would be an additional load of almost 43 percent on the total waste handling system but would represent an increase of 81 percent on the portion going to the general purpose incinerator. Conversion to total disposable food service items would add about a pound and a half of waste per meal served. This would amount to about 1,800 pounds per day at this institution. (The purpose of these examples is not to discredit the use of disposable articles but only to illustrate the need to anticipate their usage when planning waste handling and disposing facilities).

The prediction equations listed on Table III-8 should be useful in the design of new facilities or in the remodeling of those in existence. Engineering practice would apply a factor of safety to these values to provide for peak loads. At this institution, the total peak load exceeded the total mean load by 15 percent. A sum of all the unit peak loads exceeded the total mean load by 36 percent. See Table III-1. It is unlikely that all units would peak at the same time except in the case of a disaster. Increased waste quantities will result from current hospital trends toward the increased use of disposables. The weight of anticipated increases can be added to weights derived from these general equations to form a reliable basis of waste generation for future time periods. The time of day that these quantities reached the incinerator room and loading dock are recorded on Table IV-2.

Waste Disposal Practices

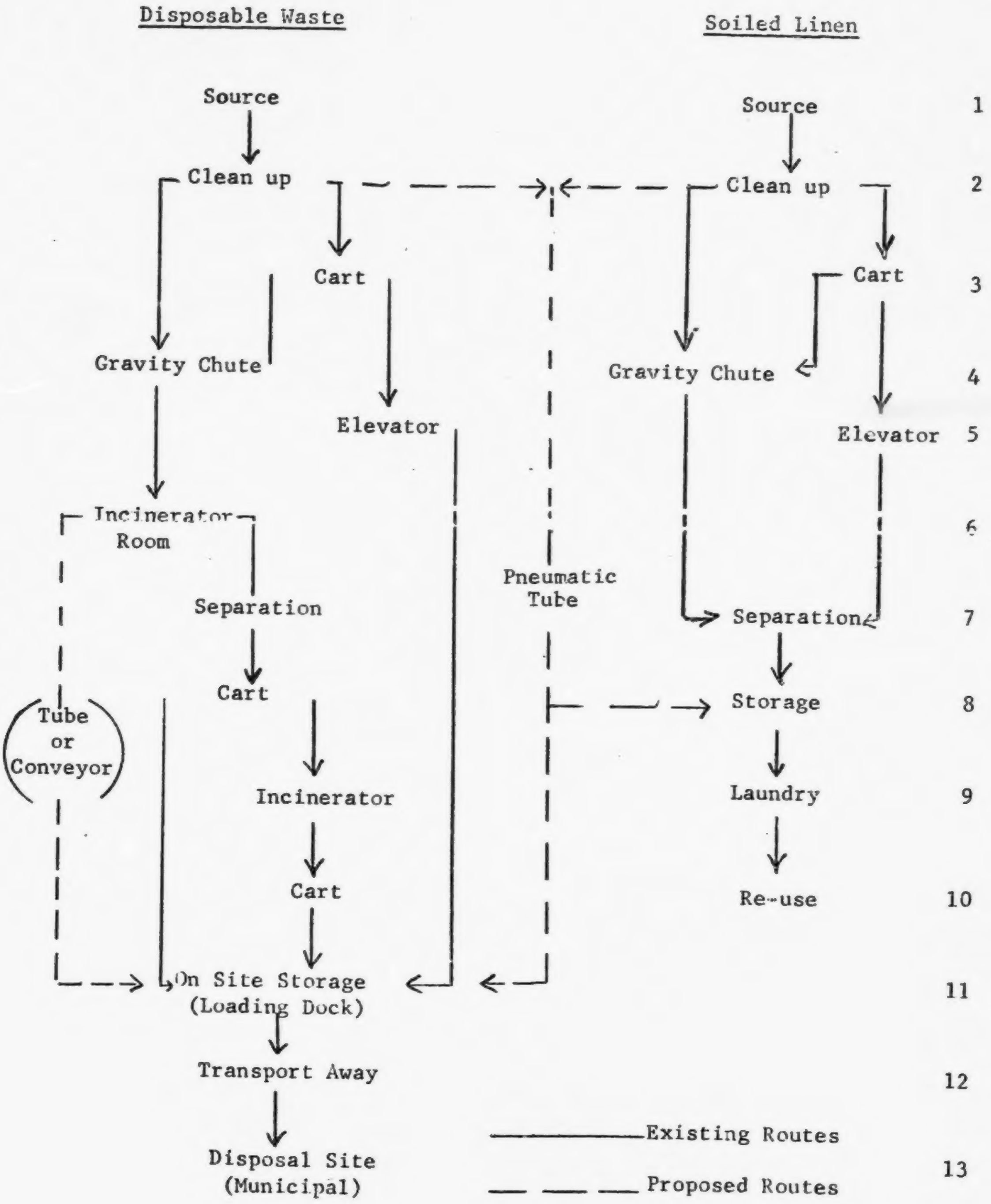
Both volume and weight of solid wastes generated are of great importance in handling, storing or disposing operations. Increased labor costs, building costs and disposal costs necessitate volume and hopefully weight reduction practices wherever possible.

Incineration is one method of volume reduction commonly used in hospitals. At this institution, approximately 66 cubic yards of refuse per day (2600 pounds) are reduced to approximately 1/2 cubic yard of ashes weighing about 200 pounds. This represents a 99 percent reduction in volume and a 92 percent reduction in weight at the incinerator room. Part of the 2400 pounds of waste that leave through the chimney is converted to carbon dioxide or other gases and dispersed to the atmosphere. Unfortunately enough is converted to fly ash and soot to cause problems with cooling towers, air conditioners and surrounding property. Without proper air pollution control devices, incinerators remove waste from containers where it can be managed and distribute it over the country side where it cannot be managed.

Residue from the incinerator and most non-combustibles are taken to the loading dock for storage until picked up and removed by the University refuse truck each morning. Figure III-1 is a flow chart showing the path taken by most of the wastes from this institution. Solid lines represent existing routes and dashed lines represent proposed routes discussed in the chapter on recommendations. As can be seen from this diagram, all waste eventually requires ultimate disposal in a location away from the Medical Center. For this institution, most of the waste is taken to the municipal landfill by university owned vehicles.

Small portions of the total waste from this institution do not follow the normal course but are handled in a special manner. These special wastes require special precaution and disposal operations and consequently have not been included

Figure III-1 Solid waste flow chart


Disposable Waste
Soiled Linen
Source
Source
1
Clean up
Clean up
2
Cart
Cart
3
Gravity Chute
Gravity Chute
4
Elevator
Elevator
5
Incinerator Room
6
Pneumatic Tube
Separation
Separation
7
Cart
Storage
8
Tube or Conveyor
Incinerator
Laundry
9
Cart
Re-use
10
On Site Storage (Loading Dock)
11
Transport Away
12
Disposal Site (Municipal)
13
Existing Routes
Proposed Routes

in the totals to either the loading dock or the general purpose incinerator.

Surgical trimmings, placentae, pathological wastes and autopsy wastes are autoclaved, refrigerated during storage, and then incinerated when quantities accumulate to make a load. Approximately eight loads (175 pounds per load) are cremated each year in a special "Human Destructor" type incinerator. At this institution, cadavers used for instruction in anatomy classes or for other work in the School of Medicine are also cremated in this special purpose incinerator. After use in the laboratory, approximately 35 bodies, averaging 135 pounds per body, are cremated each year. This adds to a total of 6,125 pounds disposed per year (20 pounds per day) resulting in about 404 pounds of ashes.

Experimental animals used for research at this institution are also handled and disposed separately from the general refuse. An average of 178.9 pounds of animals are cremated in a destructor type incinerator each working day. This weight is made up of an average of 4.6 dogs, 2.4 cats, 68.6 rats, 21.6 mice, 1.1 hamsters, 0.3 opposums, 0.2 monkeys, 1.9 rabbits, 0.9 guinea pigs, and is reduced to 7.8 pounds of ash per day. The ash and an estimated 150 pounds of corn cob bedding from the animals are taken to the loading dock each working day. (This weight is included in the totals from the loading dock).

Another special waste category requiring separate handling is volatile liquids. All flammable or dangerous chemicals, liquids or toxic compounds are stored in a separate room in the Basic Sciences area and are hauled away to a land disposal site and buried. No reliable estimations of the quantities handled each year was available.

Radioactive materials used for research or treatment are handled as prescribed by the Atomic Energy Commission under the license granted to the University Medical Center. Most radioactive wastes are discharged to the sewer after proper dilution. Solid particles are buried at a prescribed location and items of high activity are retained in protective containers until they decay sufficiently to allow disposal. Total quantities of radioactive wastes requiring disposal were considered insignificant.

Waste handling personnel reported receiving numerous punctures from disposable needles protruding from plastic waste sacks. One or two were pricked while attempting to compact refuse into sacks containing disposable needles. Minor cuts were reported from handling broken glass, and splinters have resulted from disposing of wooden crates and boxes. While no one has reported contracting disease or serious infection from these hazards, the potential still remains. Regulations require that needles and syringes must be thrown away in a condition that will not cause injury to someone or provide for their reuse if they should be removed from the waste at a later time. Crushers, ovens and containers are available for properly disposing of these hazardous items.

There were no reports of anyone scavenging in the waste for partly used or out-dated bottles of medicines or narcotics that may have been thrown away. What happens to such bottles at the municipal waste disposal site is not known. The contents of bottles that have a potential illegitimate reuse are properly flushed to the sewer if a hospital has control over the method of disposal.

Fire hazards exist in the incinerator room and in the refuse chute and there have been reports of fires in the chutes; but a sprinkler system installed at the top is usually able to control such incidents. The incinerator room and the refuse chute are separated by a fire door. There have been reports of smoke in the incinerator room but no reports of a serious fire.

Conclusions and Recommendations

Waste Generation

1. The institution studied is considered to be typical in its generation of refuse quantities. This conclusion is based on a comparison of generation rates for total refuse quantities with rates from other studies which contained institutions of similar function.
2. The existing trend to report total solid waste generation rates from hospitals on a pound per bed patient or pound per gross population basis was found to be inaccurate, unreliable and misleading.

   Hospital generation rates should be based on a common parameter that will allow comparison of hospitals of different types, functions or sizes. An "Equivalent Population" such as one defined by the American Public Health Association (6) and used in a comprehensive study of hospital wastes conducted in Los Angeles, California (1) is the most reliable basis found to date and should be used to report waste generation of total hospital solid wastes. An equivalent population is defined as an average 8 hour population census, counting outpatients at one half value. The average is based on a seven day week.
3. The prediction or reporting of waste quantities for individual units of a hospital was found to be unreliable and misleading when based on number of bed patients or gross population of that unit.

   The same unreliability was found when attempting to use the Equivalent Population as a prediction parameter. It was observed that doctors and volunteers or students were counted at more than one unit during the same day because of their mobility. Inclusion of doctors was found to bias the equivalent population figures for units while it did not affect the equivalent population figures for the total institution.

4. This study found that equations based on the total 24 hour paid staff minus the number of doctors was very reliable for predicting the quantity of refuse generated from patient care units and from certain support units of the institution studies. Prediction equations for other units were reliable when based on number of meals served or x-rays taken. All equations and their statistical reliability are listed on Table III-8.

   Since the institution studied was found to be typical in total generation quantities, it can be assumed that the unit rates are also typical.

5. The equations derived from this study should provide a reliable basis for reporting or predicting waste quantities for individual hospital units. Such equations had previously not been available. Designers and architects should find these equations useful in designing or remodeling waste handling systems in hospitals.

6. The equations developed include units grouped into three main divisions; 1) units dealing in heavy or extensive patient care; 2) units dealing in light or moderate patient care; 3) units dealing in support activities. A statistical analysis of the data supports the assumption that these equations will be usable for other institutions but this assumption requires verification. These equations are to be verified by: Selecting at another similar institution, three units in each of the three main divisions; calculating the population by summing the total paid staff minus the doctors of administrators for each unit; collecting the waste produced for at least three separate 24 hour periods for each unit; and comparing the observed results with those calculated from the equations suggested. If individual results are found to be scattered, pool the data for the three observations on each unit and compare average values with the calculated averages.

7. The equations developed in this study are empirical in origin and provide only an estimate of current mean daily quantities. They do not include all variables known to influence refuse generation, and should be adjusted in value to account for known or anticipated changes in waste handling practices at any institution. Peak loads at this institution ranged from 15 to 35 percent higher than mean daily quantities. Current trends in hospitals are toward increased use of disposable or throw-away items. The outcome of these trends must be anticipated and then added to base line values of current waste production derived from direct observations or calculated from the equations offered in this study.
8. Of the total waste generated in the hospital, only 25 to 30 percent can be considered potentially dangerous. This is due to its origin from patient care units treating communicable diseases or because of its association with surgical operations, autopsy wastes, body discharges, or pathogenic organisms. By keeping these wastes separate from all other wastes the remaining wastes need not receive the same type of treatment that is advocated for contaminated or pathogenic wastes. If all wastes are mixed together they must all be considered contaminated and treated as such.
9. Support services contributed almost 60 percent of the total weight of wastes, while the remaining 40 percent was generated by the patient care areas. The largest single producer of waste is the food service area which accounts for over 38 percent of the total wastes generated by Medical Center as a whole.

Waste Handling

1. Proper operation of a refuse incinerator in a hospital is mandatory. Hospital incinerators not equipped with adequate air pollution control devices should not be used.

2. Additional studies are needed in the area of anticipated changes in materials used in hospitals. Medical personnel, administrative personnel, equipment and materials designers, producers of disposable items, and all others concerned with health care now and in the future should be researched in order to prognosticate waste generation information for the future. These studies should not only include physical parameters, such as quantities and weights, but should also investigate social, economical and legal parameters.
3. Additional studies on the impact of mechanical waste handling devices are needed. With available waste generation data and an estimate of anticipated increases in waste production, systems approach procedures must be investigated and the components of such systems evaluated. New systems must be devised to economically handle increased quantities.

Facilities - Operational Recommendations

1. To reduce the exit of contaminated dust from the refuse and laundry chutes into the corridors, exhaust fans should be installed near the top of each chute to create a slight negative pressure. If the doors are kept closed on the chutes, this should have little effect on the air conditioning system of the hospital.
2. Refuse should be bagged at the point of generation wherever possible, and the bags should remain closed in order to reduce the possible spread of contamination. The contents of bags should never be dumped from one container to another or down the chute.
3. Soiled laundry should be contained in bags until it reaches the laundry area. The opening of bags in the corridor and the stuffing of individual sheets into the laundry chute has been proven to be a source of airborn contamination. Laundry should be handled with precautions similar to those used to handle refuse.

4. Clean or sanitary items should never be placed on the same trays or conveyances that are used to handle wastes without properly sanitizing the trays or conveyances. Infractions of this rule were observed during the course of the study.
5. Disposable syringes and needles should be made inoperative prior to disposal. This can be accomplished by cutting, crushing, melting, or sealing them in a container. Usable needles and syringes reached the loading dock almost daily. Since the hospital has no control over the municipal refuse disposal operation, it has no control over possible reuse of these devices unles they exercise proper handling procedures prior to disposal.
6. Radioactive wastes should be handled in a safe manner. Compliance with Atomic Energy Commission regulations will insure continuance of a non hazardous operation.
7. Volatile liquids must be handled with continual care. Separate storage and disposal is mandatory and should be continually maintained.
8. Care should be exercised over the disposal of unused or outdated medicinals, especially narcotics. Where there is no control over disposal operations, wastes must be handled so that there is no opportunity for them in a usable form to reach the public.
9. Reminders of safe waste-handling rules and techniques must continually be given to all staff and professionals through in-house training and information bulletins. Employees were often observed to practice unsafe and unsanitary procedures in the disposal of wastes that they generated or helped to generate. Too often people get in a hurry or become forgetful and neglect basic rules that should always be observed.

IV. PHYSICAL AND CHEMICAL COMPOSITION OF MEDICAL CENTER SOLID WASTES

Introduction

The waste generation from the units of the Medical Center was analyzed to determine physical and chemical properties. It was felt that these analyses would give better insight into the difficulties of an possible solutions to waste handling and disposal problems.

Physical analyses performed include: weight, volume, bulk density, and separation of waste into component categories.

Chemical analyses include: moisture content (really a physical parameter but was performed as part of the chemical investigations), volatile solids content, ash residue, gross calorific value (British Thermal Unit), sulfur content, phosphorus content, nitrogen content, carbon content, and hydrogen content.

Physical Analyses

Sample Preparation

Sample collection and preparation for physical analysis was described in detail in Chapter II. Basically, preparation consisted of manually sorting the waste into predetermined categories and weighing the total for each category. A flow diagram of sample preparation is shown in Figure IV-1.

Volume determinations were made by: a) measuring the size of the bulk containers at the loading dock and calculating their volumes, b) measuring the size of the waste cart in the incinerator room and calculating its volume, c) measuring the number of gallons of water it took to fill the plastic sampling and weighing containers, and d) measuring the dimensions of individual piles of waste and computing their volumes. When a container was only part full, the sampler would estimate the volume based on a relationship of what the volume would be if the container was full.

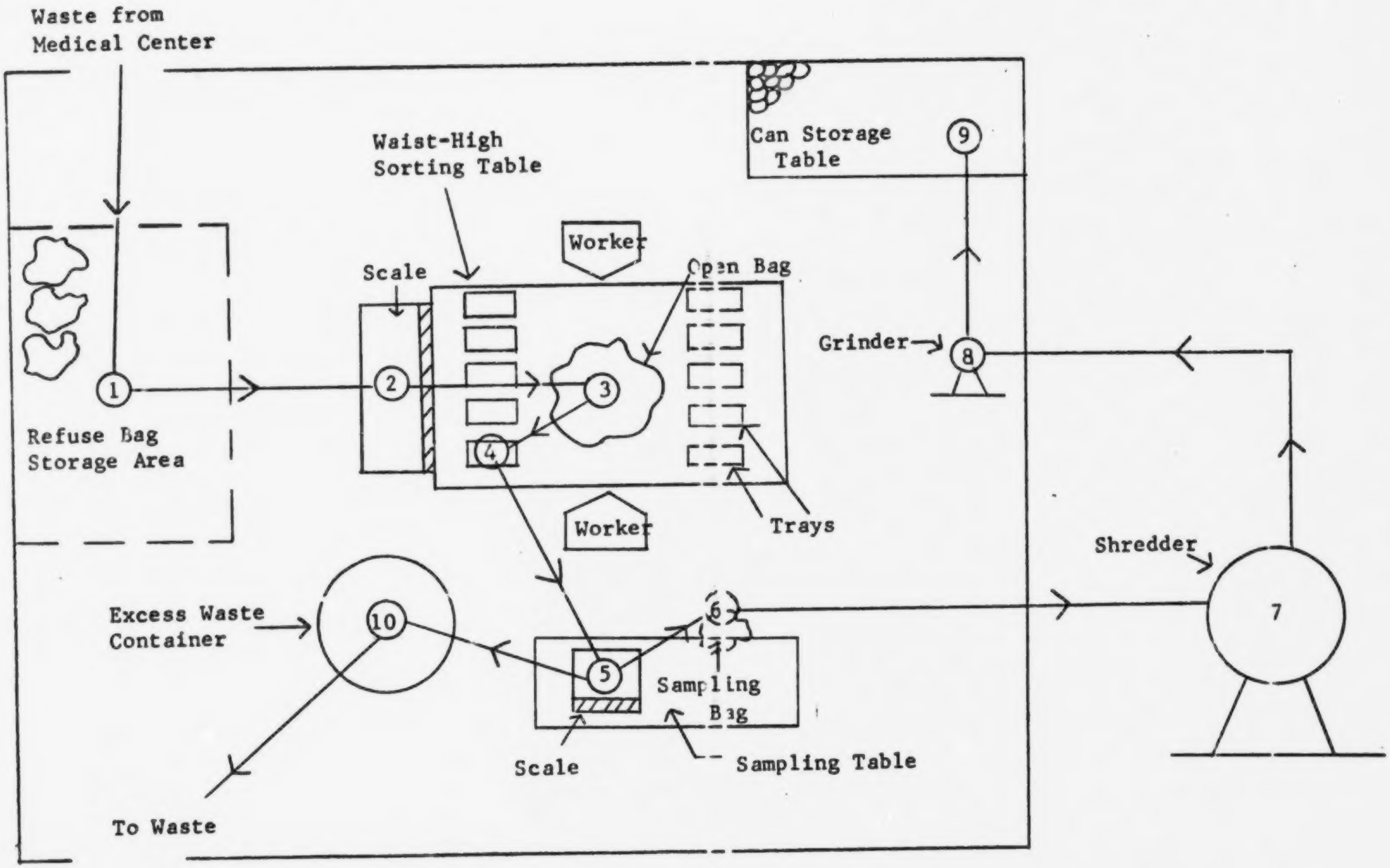

Waste from
Medical Center
Refuse Bag
Storage Area
Waist-High
Sorting Table
Scale
Worker
Open Bag
Worker
Trays
Can Storage
Table
Grinder
Shredder
Excess Waste
Container
Sampling
Bag
Scale
Sampling Table
To Waste
1
2
3
4
5
6
7
8
9
10

Figure IV-1 Physical analysis process

Estimates were spot checked periodically to determine accuracy. The samples were able to stay within 5 to 10 percent accuracy limits.

Solid Waste Densities

Density values were calculated from the measured weights and volumes. Densities at best were all relative. If the sampler or housekeeper compressed more waste into a given container by pushing with his hands or feet, the density increased accordingly. Throughout the study, a concentrated effort was made to measure the waste "in situ" as it was being handled by Medical Center personnel without manipulating it or changing existing practices.

Weights and volumes of refuse reaching the general purpose incinerator room and loading dock from both the Hospital and Basic Sciences Building were recorded for eight separate weeks during the study period. The densities (ratio of weight to volume) were computed from the data and statistical analyses were run to determine the reliability of the relationships. The density values obtained are listed on Table IV-1, complete with R squared values and standard errors. The time of day that these quantities reached the incinerator room and loading dock are recorded on Table IV-2.

Waste from the Hospital to the incinerator room comes mainly from patient care areas and includes very little glass or metal. The waste is loosely packed in plastic bags and takes up considerable volume, often accumulating in the chute up to the first floor (30 feet above). The waste is mainly paper or plastic and consequently has a low weight to volume ratio (low density). The refuse from Basic Sciences to the incinerator is also composed predominately of paper products but contains more office paper, magazines and heavier articles. Since this waste is picked up in carts and wheeled to the incinerator room, the janitor who collects it often compacts his load into the cart to get more in per trip and this increases the density. This partially explains the difference of density between the two sources.

Table IV-1 Weight-volume relationships

SOURCE OF WASTE	DESTINATION	DENSITY LBS/CU. YD.	R^2	STANDARD ERROR
Hospital	Incinerator Room	36.7	0.991	1.290
Hospital	Loading Dock	111.2	0.915	12.601
Hospital	(Combined Total)	40.1	0.841	4.482
Basic Sciences	Incinerator Room	64.2	0.964	4.573
Basic Sciences	Loading Dock	86.2	0.857	12.781
Basic Sciences	(Combined Total)	74.2	0.865	7.489
Medical Center	Incinerator Room	37.2	0.979	1.394
Medical Center	Loading Dock	100.7	0.879	9.531
Medical Center	(Combined Total)	41.4	0.824	3.432
Medical Center (Refuse Truck Weights)	Disposal Site	149.1	-	-
Medical Center (Storage Container Weights)	Disposal Site	216.1	-	-

Table IV-2 Mean hourly solid waste generation totals (weight in pounds)

UNIT	TIME	TO LOADING DOCK	TO INCINERATOR ROOM	TOTAL
Hospital	0-6 A.M.	0.0	0.0	0.0
	6-8 A.M.	13.4	215.4	228.8
	8-10 A.M.	234.1	219.2	453.3
	10-12 noon	172.4	249.8	422.2
	12-2 P.M.	233.1	187.4	420.5
	2-4 P.M.	125.3	431.2	556.5
	4-6 P.M.	55.7	156.5	212.2
	6-8 P.M.	249.1	114.9	364.1
	8-10 P.M.	80.6	180.5	261.1
	10-12 P.M.	127.0	173.4	300.4
	TOTAL	1290.8	1928.3	3219.1
Basic Sciences	0-6 A.M.	0.0	0.0	0.0
	6-8 A.M.	77.7	0.0	77.7
	8-10 A.M.	45.3	9.9	55.2
	10-12 noon	40.0	4.5	44.5
	12-2 P.M.	71.0	1.3	72.3
	2-4 P M.	127.7	9.8	137.5
	4-6 P.M.	51.6	27.2	78.5
	6-8 P.M.	190.3	323.2	513.5
	8-10 P.M.	90.7	132.8	223.5
	10-12 P.M.	63.8	22.4	86.2
	TOTAL	758.0	531.3	1289.3
Medical Center	0-6 A.M.	0.0	0.0	0.0
	6-8 A.M.	73.0	215.4	288.4
	8-10 A.M.	268.8	226.8	495.6
	10-12 noon	203.1	253.2	456.3
	12-2 P.M.	287.5	188.3	475.8
	2-4 P.M.	223.3	438.8	662.1
	4-6 P.M.	95.3	177.3	272.6
	6-8 P.M.	395.2	363.0	758.2
	8-10 P.M.	150.2	282.4	432.6
	10-12 P.M.	176.0	190.6	366.6
	TOTAL	1872.5	2336.0	4208.5

Since the Hospital contributes the major portion of the waste taken to the incinerator room, the value listed for the total Medical Center is closer to that of the Hospital.

Wastes from the Hospital to the loading dock are composed of glass, metal, food wastes, and other items not easily burned. Densities of waste to the loading dock are about three times that of the waste to the incinerator room. The difference is not so great coming from Basic Sciences because there is less glass, metal and other heavy items, and more empty boxes in this waste. Values of density for the entire Medical Center give volumes greater than anticipated from review of other investigations in the literature. If the total volume is divided by the number of bed patients, the volume production rate is 0.21 cubic yards or 5.71 cubic feet per patient. If the equivalent population values are used, this rate reduces to 1.75 cubic feet per patient as opposed to 0.5 to 1.0 cubic feet often quoted.

Volumes and weights from 92 observations of the refuse truck picking up waste from the loading dock resulted in another value for density. The mean density value from these observations was 149 pounds per cubic yard. These observations often included large quantities of empty boxes occupying extensive volume prior to loading into the packer mechanism of the refuse truck. Densities of the waste in the containers along averaged 216 pounds per cubic yard. Waste in the containers was composed mostly of ashes, glass, metal, casts and other items that were not combustible.

Waste Classification

Solid wastes originating from hospitals have been classified in many different ways by equally as many different individuals. They are broadly classified as food wastes (garbage), combustible material, and non-combustible material, and handled accordingly. Most wastes coming from patient care areas are classified as infectious while wastes originating from patients in isolation are normally classified as highly infectious. Often the total wastes become mixed and many authorities have chosen to

Table IV-3 Hospital areas generating wastes and their typical waste products (30)

Area	Waste Products
Administration	Paper goods
Obstetrics department including patients' rooms	Soiled dressings; sponges; placentas; waste ampules, including silver nitrate capsules; needles and syringes; disposable masks; disposable drapes; sanitary napkins; disposable blood lancets; disposable catheters and colostomy bage; disposable enema units; disposable diapers and underpads; disposable gloves; etc.
Emergency and surgical departments, including patients' rooms	Soiled dressings; sponges; body tissue including amputations; waste ampules; disposable masks; needles and syringes; drapes; casts; disposable blood lancets; disposable emesis basins; Levine tubes; Catheters; drainage sets; colostomy bags; underpads; surgical gloves; etc.
Laboratory, morgue, pathology and autopsy rooms	Contaminated glassware, including pipettes, petri dishes, specimen containers and specimen slides; body tissue; organs; bones.
Isolation rooms other than regular patients' rooms	Paper goods containing nasal and sputum discharges; dressings and bandages; disposable masks; leftover food; disposable salt and pepper shakers; etc.
Nursing stations	Ampules; disposable needles and syringes; paper goods.
Service areas	Cartons; crates; packing materials; paper goods; metal containers, including tin cans, drums, etc.; bottles, including food containers, solution bottles, and pharmaceutical bottles; wastes from public and patient rooms, including paper goods, flowers, etc.; waste food materials from the central and floor kitchens; wastes from x-ray; discarded furniture; rags; etc.

Table IV-4 Additional Hospital areas generating wastes and their typical waste products (30)

Area	Waste Products
Service areas	Dust and particulate matter from heating and ventilation equipment; soiled linens and uniforms; lint from washing and drying cycles; empty detergent, bleach, and disinfectant containers; etc.
Teaching and research areas	Paper; bottles; dry rubbish; infectious wastes (mostly animal remains including carcasses and organs); cadavers and organs from surgery; ashes from crematories; etc.
Food preparation areas	Wooden crates; cardboard and plastic cartons containing food; food trimmings; cans; bottles; aluminum and plastic containers; paper tray covers; disposable eating utensils; food wastes; etc.

Table IV-5 APWA Classification of refuse materials

Kind or Character	Composition or Nature		Origin or Source
Garbage	Wastes from the preparation, cooking, and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meats		From: households, institutions, and commercial concerns such as: hotels, stores, restaurants, markets, etc.
Rubbish or Mixed Refuse	Combustible (primarily organic)	Paper, cardboard, cartons Wood, boxes, excelsior Plastics Rags, cloth, bedding Leather, rubber Grass, leaves, yard trimmings	
	Noncombustible (primarily inorganic)	Metals, tin cans, metal foils Dirt Stones, bricks, ceramics, crockery Glass, bottles Other mineral refuse	
Ashes	Residue from fires used for cooking, heating buildings, incinerators, etc.		
Bulky Wastes	Large auto parts, tires Stoves, refrigerators, other large appliances Furniture, large crates Trees, branches, palm fronds, stumps, flotage		From: streets, sidewalks, alleys, vacant lots, etc.
Street refuse	Street sweepings, dirt Leaves Catch basin dirt Contents of litter receptacles		
Dead animals	Small animals: cats, dogs, poultry, etc. Large animals: horses, cows, etc.		
Abandoned vehicles	Automobiles, trucks		
Construction & Demolition wastes	Lumber, roofing, and sheathing scraps Rubble, broken concrete, plaster, etc. Conduit, pipe, wire, insulation, etc.		
Industrial refuse	Solid wastes resulting from industrial processes and manufacturing operations, such as: food-processing wastes, boiler house cinders, wood, plastic, and metal scraps and shavings, etc.		From: factories, power plants, etc.
Special wastes	Hazardous wastes: pathological wastes, explosives, radioactive materials Security wastes: confidential documents, negotiable papers, etc.		Households, hospitals, institutions, stores, industry, etc.
Animal and Agricultural wastes	Manures, crop residues		Farms, feed lots
Sewage treatment residues	Coarse screenings, grit, septic tank sludge, dewatered sludge		Sewage treatment plants, septic tanks

SOURCE: APWA - REFUSE COLLECTION PRACTICES

Table IV-6 Medical Center classification of refuse materials

(APWA Classification)		(Study Classification)
GARBAGE	FOOD:	Coffee Grounds Scraps
RUBBISH (conbustible)	PAPER:	Office Carbon Newspaper, magazine Towels Sacks Cardboard Cups Candy, cigarette wrappers Other
	PLASTICS:	Hard Foam Bags
	FILM:	X-ray plates
	CLOTH:	Cotton Cotton tape Gauze
	RUBBER:	
	WOOD:	
RUBBISH (non-combustible)	DUNNAGE:	
	GLASS:	
	METALS:	
	MOLDS, CASTS:	
ASHES	ASHES:	
DEAD ANIMALS	EXPERIMENTAL ANIMALS:	
CONSTRUCTION, DEMOLITION WASTE	CONSTRUCTION WASTE:	
SPECIAL WASTES	RADIOACTIVE, PATHOLOGICAL, AUTOPSY, SURGICAL	
ANIMAL, AGRICULTURAL WASTE	ANIMAL DROPPINGS	

Table IV-7 Unit weight by categories
(values in percent of weight)

	META	PSYC	GMED	GMED	PED	GYN	SURG	SURG	OB	ORTH	ORTH	OR	IC
Office Paper	7.9	5.1	3.6	1.9	3.7	3.4	2.1	2.7	3.1	3.5	4.1	1.9	2.9
Carbon Paper	0.8	0.3	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Newspapers,Magazines	9.0	4.8	5.9	7.3	2.2	4.4	3.6	3.4	3.9	2.2	2.2	0.4	0.4
Paper Towels	24 3	24.0	15.8	17.6	14.9	13.7	9.8	10.4	17.6	12.1	11.8	12.4	8.8
Paper Sacks	4.2	4.4	4.2	6.7	4.5	7.0	7.0	6.7	5.2	7.5	5.4	5.6	4.6
Cardboard	5.4	4.9	6.8	5.4	5.0	3.7	6.4	8.8	5.7	5.5	5.7	11.3	7.4
Paper Cups	6.8	15.7	6.9	8.2	7.1	7.1	6.5	6.0	4.4	11.1	8.3	3.7	5.4
Candy, Cig. Wrappers	1.1	2.9	0.8	0.8	0.7	1.0	1.3	0.6	1.5	0.7	0.7	0.4	0.8
Other Paper	0.8	0.0	0.5	0.1	5.3	2.2	0.7	0.5	0.0	0.3	0.2	0.0	0.2
TOTAL PAPER	60.3	62.1	44.5	48.0	43.6	42.6	37.4	39.1	41.5	42.9	38.4	35.7	30.5
Hard Plastic	4.3	3.4	8.1	5.1	7.0	4.3	4.2	4.6	1.7	4.5	5.9	2.6	8.1
Form Plastic	0.0	0.2	0.2	0.3	0.0	0.0	0.5	0.0	0.0	1.3	0.1	0.0	0.2
Plastic Bags Etc.	3.3	6.1	3.0	3.9	5.5	3.0	7.8	6.4	3.9	4.6	3.7	3.2	3.2
TOTAL PLASTIC	7.6	9.7	11.3	9.3	12.5	7.3	12.5	11.0	5.6	10.4	9.7	5.8	11.5
Glass	7.3	2.1	26.2	25.9	11.8	18.9	21.9	11.6	7.4	18.8	32.2	28.6	35.6
Rubber	0.3	0.7	1.1	1.1	1.6	2.1	1.8	1.9	1.6	1.7	1.6	2.4	4.4
Metals	4.7	5.9	1.3	1.3	0.9	0.7	0.4	0.7	6.9	1.2	0.6	2.7	1.2
Cloth, Gauze, Cotton	11.2	5.7	11.1	10.3	27.2	25.5	17.5	30.1	31.9	11.1	11.7	16.0	14.7
Food	2.3	5.1	2.4	2.0	1.3	0.9	1.3	1.3	2.1	2.5	1.3	2.0	0.6
Coffee grounds	2.7	5.0	0.0	0.2	0.0	0.0	0.3	0.0	1.3	0.0	0.0	1.6	0.1
Film, X-ray Plates	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.5
Molds, Casts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	3.9	0.5	0.2	0.0
Wood	0.2	0.3	0.1	0.2	0.2	0.2	0.0	0.1	0.2	0.2	0.1	0.1	0.3
Dunnage	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ashes	1.0	2.0	0.5	0.6	0.3	0.7	0.1	0.3	0.2	0.8	0.5	0.0	0.1
Animal Droppings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	2.5	1.3	1.5	1.1	0.4	1.1	6.7	3.7	1.3	6.4	3.6	4.7	1.2
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100

Table IV-7 (continued)

	2ND	ER	CLIN	ADMIN	CAFE	GIFT	GRND	BASE	HOSPITAL TOTAL	BSB TOTAL
Office Paper	7.0	6.9	15.1	44.3	2.5	4.4	11.2	4.9	5.9	13.7
Carbon Paper	1.5	0.1	0.1	6.4	0.0	0.4	0.9	1.0	0.6	0.6
Newspaper,Magazines	5.7	5.7	2.9	21.9	1.8	4.0	2.4	1.8	4.3	12.3
Paper Towels	8.0	17.6	25.9	7.6	19.3	7.4	19.8	12.0	12.9	21.0
Paper Sacks	2.1	6.5	6.6	2.8	2.7	1.6	2.0	4.6	5.0	3.9
Cardboard	15.0	7.2	8.7	9.3	26.2	57.0	42.2	23.0	10.4	13.5
Paper Cups	2.8	5.0	3.8	1.0	23.5	8.8	1.9	1.3	5.7	1.7
Candy, Cig. Wrappers	0.5	1.6	0.8	0.9	6.7	2.2	1.7	0.6	1.0	0.8
Other Paper	0.0	0.2	1.0	0.2	0.4	0.4	0.1	0.1	0.6	0.3
TOTAL PAPER	47.6	50.8	64.9	94.2	83.1	86.2	82.2	49.3	46.4	67.8
Hard Plastic	11.4	3.8	2.4	1.1	1.9	2.6	3.2	2.8	5.4	2.4
Form Plastic	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.2
Plastic Bags Etc.	2.7	2.7	2.3	1.9	3.6	2.6	1.5	2.3	4.0	1.3
TOTAL PLASTIC	14.4	6.5	4.7	3.1	5.5	5.2	4.7	5.1	9.6	4.4
Glass	25.8	13.4	3.2	0.1	0.1	0.0	1.6	3.7	18.4	10.7
Rubber	3.0	2.8	1.7	0.0	0.4	0.0	0.1	9.2	2.1	3.1
Metals	3.1	1.3	2.5	0.6	0.9	0.9	1.3	1.4	1.9	4.7
Cloth, Gauze, Cotton	6.0	16.6	13.2	0.5	2.1	1.4	1.3	24.9	15.6	1.3
Food	0.8	2.1	1.8	0.8	5.3	2.7	3.7	1.1	1.6	2.1
Coffee	0.1	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.4	0.6
Film, X-ray Plates	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Molds, Casts	0.0	3.1	1.8	0.0	0.0	0.0	0.0	0.0	0.3	2.3
Wood	0.3	1.0	1.6	0.0	0.0	0.0	0.2	0.1	0.2	0.2
Dunnage	1.6	0.0	0.0	0.0	0.0	0.5	0.0	0.3	0.2	0.2
Ashes	0.5	0.7	0.0	0.5	1.1	1.1	0.7	0.1	0.4	0.4
Animal Droppings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Other	[illegible]	1.9	4.4	0.1	0.0	2.1	4.1	4.8	2.8	1.8
TOTAL	100	100	100	100	100	100	100	100	100	100

consider all waste originating from hospitals as infectious and require special disposal techniques (incineration) even though wastes originating in administrative areas or from central receiving departments are no different than wastes from other institutions (schools, office buildings) in a community.

Tables IV-3 and IV-4 show general classifications of waste products from hospitals and the areas of generation as outlined by Oviatt (30). Segregation in such detail was not considered necessary for accomplishing the objectives of this study but the classification system was considered sufficiently informative to include with the report.

Table IV-5 shows the American Public Works Association (APWA) classification for all refuse materials. Table IV-6 shows the classification system used during this project and its relationship to the APWA system. The categories used in this study were chosen for ease of identification, facility in sorting, and use in later analysis. Quantities of waste generated in each category by each unit of the hospital are shown later in this chapter.

The 24 hour accumulations of waste from each of the units were separated into the designated categories and each category was weighed. The mean daily percentages for each category from each Hospital unit are listed on Table IV-7. Paper, in various sub-categories was high from all units and accounted for 46 percent of the total Hospital weight. Either glass or cloth-gauze-cotton categories were second highest depending on the particular unit source. Note that paper towels alone account for 13 percent of the total hospital waste by weight but account for a much higher percent' by volume. Plastic percentages were not significant weightwise, but a plastic bottle takesup just as much volume as a glass bottle and can be more difficult to dispose. An increased use of plastics could decrease total weights while increasing total volumes.

The mean percentages for each day of the week in each category are shown for the Hospital on Table IV-8 and for the Basic Sciences on Table IV-9. It is important to note that these percentages do not include food preparation or food scrapping wastes nor do they include experimental animals or pathological wastes. Table IV-10 shows the mean percentages for the Hospital (except kitchen and cafeteria), main kitchen and cafeteria, Hospital total, Basic Sciences (except kitchen, Basic Sciences kitchen, Basic Sciences total, and Medical Center total. This table gives a more realistic overview of percentages of waste (by weight) by each of the various categories.

The figures in the preceding tables reflect the percentages by weight of the various categories of waste. Table IV-11 shows the actual weights for each of the categories measured for the main kitchen of the Hospital. This information is significant since approximately one third (by weight) of all the refuse generated in the Hospital comes from the main kitchen. Table IV-11 is divided into food preparation and food scrapping activities. The wastes generated by these activities are indicated for each of the days sampled.

Conclusions

It is estimated that if the Hospital converted to total disposable food service items (including trays) it would add approximately 1,800 pounds per day to the waste load. This would more than double present waste quantites from the main kitchen. Since most of the disposable items are low in weight per unit volume, this would add very high volumes of waste to be handled and require some type of on-site compactor or volume reduction device to accommodate the loads. The proportion of paper and plastics would greatly increase if such a conversion were to take place.

It is estimated that if the Hospital converted to disposable linen the increased weight of refuse requiring disposal would be approximately 2,000 pounds. This is

Table IV-8 Daily Hospital refuse generation by category
(values in percent of weight)

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY	WEEKLY TOTAL
Office Paper	6.95	7.07	7.55	4.80	4.97	4.74	3.73	5.9
Carbon Paper	0.83	0.74	0.57	0.41	0.65	0.00	0.23	0.6
Newspapers, Magazines	5.21	5.59	2.76	3.74	4.21	4.01	4.50	4.3
Paper Towels	14.21	13.10	12.35	12.41	12.23	13.99	12.34	12.9
Paper Sacks	5.06	5.10	4.70	5.34	4.79	5.15	4.84	5.0
Cardboard	9.63	7.72	12.50	17.13	8.46	8.16	5.80	10.4
Paper Cups	5.62	6.33	3.75	4.66	6.01	8.46	7.54	5.7
Candy, Cig. Wrappers	0.88	0.78	0.83	1.00	0.96	1.37	1.12	1.0
Other Paper	2.42	0.40	0.60	0.06	0.26	0.10	0.29	0.6
Hard Plastic	4.84	6.21	4.20	5.76	6.40	4.78	5.69	5.4
Foam Plastic	0.14	0.37	0.46	0.10	0.06	0.00	0.00	0.2
Plastic Bags, Etc.	2.83	4.46	8.43	2.90	2.13	2.82	3.83	4.0
Glass	18.30	19.18	14.74	15.11	22.34	18.67	23.07	18.4
Rubber	1.47	2.40	2.80	2.35	1.82	1.54	2.16	2.1
Metals	1.85	2.31	1.80	1.80	1.57	1.67	2.07	1.9
Cloth, Gauze, Cotton	14.12	11.07	16.02	15.75	16.81	20.25	17.97	15.6
Food	1.99	1.58	1.32	1.55	1.57	2.01	1.55	1.6
Coffee Grounds	0.25	0.41	0.44	0.73	0.09	0.30	0.32	0.4
Film, X-ray Plates	0.35	0.06	0.00	0.02	0.04	0.00	0.10	0.1
Molds, Casts	0.09	0.47	0.00	1.29	0.09	0.00	0.00	0.3
Wood	0.33	0.27	0.15	0.18	0.16	0.11	0.14	0.2
Dunnage	0.00	0.00	0.00	0.00	1.26	0.00	0.05	0.2
Ashes	0.32	0.47	0.33	0.32	0.46	0.52	0.53	0.4
Animal Droppings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Other	2.26	3.91	3.70	2.59	2.66	1.35	2.13	2.8
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.0

Table IV-9 Daily Basic Sciences refuse generation by category
(values in percent of weight)

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	WEEKLY TOTAL	95% CONFIDENCE INTERVAL	
							LOW LIM	UP LIM
Office Paper	15.9	13.4	18.3	8.9	12.8	13.7	10.6	16.8
Carbon Paper	0.6	0.7	0.4	0.6	0.7	0.6	0.5	0.7
Newspapers, Magazines	11.9	7.5	16.6	10.8	15.1	12.3	9.1	15.4
Paper Towels	18.8	24.3	22.7	22.3	17.7	21.0	18.6	23.5
Paper Sacks	3.7	4.4	1.8	4.8	4.6	3.9	2.9	5.0
Cardboard	13.3	17.2	9.5	13.0	14.3	13.5	11.1	16.0
Paper Cups	1.9	2.1	1.8	1.4	1.5	1.7	1.5	2.0
Candy, Cig. Wrappers	1.1	0.6	0.8	0.7	0.8	0.8	0.6	1.0
Other Paper	0.2	0.0	0.2	0.4	0.6	0.3	0.1	0.5
Hard Plastic	2.9	2.8	1.9	2.8	1.5	2.4	1.8	2.9
Foam Plastic	0.1	0.4	0.1	0.2	0.3	0.2	0.1	0.3
Plastic Bags, Etc.	0.9	0.9	0.7	5.2	0.9	1.8	0.1	3.5
Glass	12.7	12.1	10.3	5.8	12.8	10.7	8.2	13.3
Rubber	3.6	0.3	0.3	9.0	1.2	3.1	-0.2	6.3
Metals	5.0	3.8	5.1	5.8	4.0	4.7	4.0	5.5
Cloth, Gauze, Cotton	1.2	1.3	1.5	1.7	0.9	1.3	1.0	1.6
Food	1.8	1.5	2.9	2.3	2.2	2.1	1.7	2.6
Coffee Grounds	0.5	0.7	0.2	0.4	1.0	0.6	0.3	0.9
Film, X-ray Plates	0.0	0.0	0.1	0.0	0.3	0.1	-0.0	0.2
Molds, Casts	1.4	1.3	3.3	2.2	3.3	2.3	1.4	3.2
Wood	0.2	0.1	0.3	0.1	0.2	0.2	0.1	0.3
Dunnage	0.1	0.3	0.1	0.3	0.2	0.2	0.1	0.3
Ashes	0.3	0.2	0.4	0.4	0.7	0.4	0.2	0.6
Animal Droppings	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.2
Other	1.8	3.9	0.6	0.7	2.3	2.0	0.6	3.1
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	74.9	125.7

Table IV-10 Mean Medical Center and Food Service waste generation by category
(Values in percent of weight)

	Hospital	Main Kitchen	Hospital Total	Basic Sciences	Basic Sciences Kitchen	Basic Sciences Total	Medical Center Total
Total paper	46.2	29.5	39.1	68.0	44.4	62.0	39.0
Total plastic	9.6	----	5.5	4.4	----	3.3	5.5
Glass	18.5	4.0	12.2	10.7	6.5	9.7	12.2
Rubber	2.1	----	1.2	3.0	----	2.3	1.2
Metal	1.9	4.0	2.8	4.7	6.5	5.2	2.8
Cloth & Gauze	15.6	----	8.9	1.3	----	1.0	8.8
Food & Coffee	2.0	62.5	28.0	2.7	42.6	12.6	28.0
All other	4.1	----	2.3	5.2	----	3.9	2.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table IV-11 Sampling data for the Main Kitchen.
Weights in Pounds

	Monday 4/7/69	Tuesday 3/25/69	Wednesday 2/26/69	Thursday 1/30/69	Friday 11/15/69	Saturday 10/26/69	Sunday 4/20/69
Food preparation							
paper	170	152	143	106	260	117	97
food	518	313	370	351	432	443	251
cans & bottles	84	88	115	117	119	108	108
Food scrapping							
paper	229	212	227	315	265	205	214
food	518	655	523	514	282	331	236
Totals	1519	1420	1373	1403	1358	1204	906

based on non-woven disposable sheets weighing about 25 percent of what a linen sheet weighs. If such a conversion were to take place, the proportions of paper and/or plastics would increase significantly.

The quantities of waste generated in each of the categories reflects the type of materials used and to a degree, the type of service given by the particular unit of the Hospital. Any significant change in the types or physical characteristics of the materials used in the units will naturally be reflected in the wastes. Paper and plastics together comprise well over half of the total waste load (by weight). Since most of the wastes from the Hospital are low density wastes, (41 lbs/cu.ft.) the volumes generated are very high (about 2-1/2 cu.yds./100 lbs). Consequently most hospitals have volume reduction equipment in the form of incinerators or on-site compactors. Without some method of reducing the volume, the storage requirements would be extremely high.

The design of refuse handling facilities and equipment should reflect the physical nature of the waste and provide the necessary volume storage or volume reduction capacities. Automatic waste handling equipment is being developed to process the large quantities of materials that flow through hospitals. Materials handling expertise is being directed toward the problems in hospitals but without information such as that presented in these tables, it could well be misdirected.

Hospitals which are required to pay for waste disposal on a volume basis should use every means available to reduce the volume while those hospitals which pay on a weight basis, may not be as concerned about volume reduction.

CHEMICAL ANALYSIS

Sample Preparation

Sampling procedures and initial sample preparation were discussed in detail in Chapter II. Any additional preparation necessary prior to chemical analysis is described as part of the specific test procedures for each chemical test. For most analyses the procedures outlined in Appendix B of Municipal Refuse Disposal (91) were followed. Where modifications to these analyses were required or where procedures were used that are not contained in Appendix B of Municipal Refuse Disposal, such deviations or additions are mentioned in addition to the standard procedure for each chemical analysis. That is listed in Appendix B of this report.

The samples taken from the covered tin containers were systematically analyzed in order to obtain maximum efficiency of equipment. The tests conducted were as follows in order of testing: Moisture content, Volatile solids content, ash residue, Gross calorific value (B.T.U.) Sulfur content, Phosphorus content, Nitrogen content, Carbon content and Hydrogen content.

Statistical analyses were run on all chemical data to increase the degree of reliability for the results and conclusions. Means, standard deviations, standard error of this means, and ninety five percent confidence intervals were the statistical analyses used for this portion of the study.

Moisture Content

The true moisture content of the solid waste as generated from the Medical Center is not reflected by this data as shown in Table IV-12. The sample preparation process was not conductive to moisture retention. The separation into categories, rough grinding through the "Davis-Built" grandulator and fine grinding through the Standard Model 3 Wiley Mill all allowed the samples to be in contact with the air and to dry out.

Table IV-12 Moisture content
(Percent of Total Weight)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	76	5.054	0.149	5.351
Basic Sciences	101	5.455	0.166	5.784
Total Medical Center	177	5.283	0.115	5.508

No tests were run on the "as received" refuse to determine actual moisture percentages but visual observations on wastes coming from the kitch laboratories, maternity, intensive care, surgery and areas where burn patients are cared for confirmed that wastes were often very moist.

Since over half of the waste was paper, much of the moisture was absorbed in the waste handling process. Only when partially filled containers were dumped did moisture seep from the refuse.

The true moisture content is important for incinerator operation and heat reclamation. Moisture adds to the weight of refuse for disposal and can increase disposal costs where weight is the parameter for cost determination.

Since the moisture content of the refuse will vary significantly from one hospital unit to another, it was not felt necessary to obtain "as received" moisture values. This should be done on an individual hospital basis if it is required. Excessive moisture content will lower the effective heating value of the refuse if heat recovery operations are anticipated.

Volatile Solids Content

The values for volatile solids content are calculated on the portion of the sample that was ground. Excluded are the metal, wood, glass, rubber and hard plastic components of the waste. Since glass and metal make up approximately 20 percent of the total waste by weight the mean value listed in Table IV-13 for the total Medical Center should be reduced to approximately 76 percent.

Table IV-13 Volatile solids content
(Percent of Total Weight)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	76	96.372	0.211	96.794
Basic Sciences	101	95.576	0.246	96.062
Total Medical Center	177	95.917	0.168	96.246

Glass and metal are normally excluded from the waste that is incinerated, consequently these values are not too different from what occurs in actual practice. Approximately 92 percent by weight of the waste incinerated leaves through the chimney leaving an ash residue of about 8 percent. The refuse incinerator at the Medical Center is not equipped with after burners or air pollution control devices and consequently all the material that leaves the stack has not volatized. Fly ash, unburned particles and products of incomplete combustion shower the neighborhood making the 92 percent apparent weight reduction seem better than it really is.

The volatile solids content of the samples does show that with proper incineration, the wastes can be significantly reduced in both weight and volume. This is primarily due to the high percentages of paper, plastic, cloth, and other materials that are combustible.

Ash Residue

The ash residue represents that portion of the waste which is not volatile. Because of this relationship, most of what was discussed under Volatile Solids content is applicable for ash content, but with inverse results. The values listed in Table IV-14 are low because of the exclusion of glass and metal from the samples. Adjusted values would range closer to 24 percent by weight.

Table IV-14 Ash Residue - Volatile solids test
(Percent of Total Weight)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	76	3.627	0.206	4.038
Basic Sciences	101	4.423	0.242	4.902
Total Medical Center	177	4.081	0.166	4.407
	Carbon train test			
Hospital	76	2.707	0.222	3.151
Basic Sciences	101	3.651	0.300	4.245
Total Medical Center	177	3.246	0.198	3.635

Gross Calorific Value

The gross calorific value of the refuse provides a measure of its heating potential. Incinerators are designed around the heat value of the fuel to be used when heat recovery or heat dissipation are of prime importance. Knowing the calorific value of hospital refuse, expressed in B.T.U.'s per pound of refuse, provides design engineers with a helpful tool. The B.T.U. value allows us to compare one fuel with another.

The calorific value for municipal refuse varies from about 5,500 BTU/pound to 10,000 BTU/pound. The values obtained for this refuse averaged around 8,000 BTU/pound and did not vary much over 500 BTU/pound above or below this mean value. Having a fuel with a reliable heating value is an important factor.

The figures in Table IV-15 do not include the non-grindable metal, glass, wood, rubber and hard plastic. The metal and glass would not add to the BTU value but wood, rubber and hard plastic would. The values in Table IV-15 were obtained from samples having low moisture contents. A higher moisture content would decrease the BTU value per pound of refuse. It is assumed that the low moisture content is offset by the lack of wood, rubber and hard plastic which could tend to cancel each other out.

Table IV-15 Gross calorific value
(Values in B.T.U./pound)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	76	8381.391	112.537	8606.461
Basic Sciences	101	7612.477	98.512	7807.527
Total Medical Center	177	7942.508	79.327	8097.988

Coal has BTU per pound values ranging from 10,000 to over 14,000 with a high percentage of coals having around 13,000. Hospital refuse at 8,000 BTU per pound is not as good as coal but since it must be disposed of anyway and since it contains possible pathogenic organisms that can be killed by heat, it makes good sense to incinerate where air pollution control regulations can be satisfied both in equipment and operation.

Sulfur Content

The sulfur in refuse can react to form sulfur dioxide (SO_2) when incinerated. This gas can then add to air pollution problems if sufficient quantities are generated. In certain areas of the country coal with a sulfur content over 2 percent is banned because of the sulfur dioxide that is released. Coal is considered low sulfur coal when the sulfur content is 1 percent or less.

The sulfur content of this refuse was about 0.2 percent or one fifth that of a low sulfur coal. Since it would take almost twice as much refuse as coal to give the same B.T.U. value it would be more realistic to figure twice as much sulfur liberated or about 0.4 percent when comparing refuse to coal. Even at this figure, the sulfur content of refuse does not appear to be a serious problem during incineration as seen in Table IV-16.

Table IV-16 Sulphur content
(Percent of Total Weight)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	76	0.211	0.018	0.247
Basic Sciences	101	0.199	0.014	0.226
Total Medical Center	177	0.204	0.011	0.226

If the refuse is landfilled and anaerobic conditions occur, the sulfur in the refuse can be reduced to hydrogen sulfide (H_2S) which can be quite odiforous. Other than that, there should be no problems with sulfur in waste disposal operations.

Phosphorus Content

The phosphorus content of the refuse is very low, 0.03 percent. Phosphorus content of municipal refuse ranges from 0.12 to 0.70 percent as shown on Table IV-17

The phosphorus content of this refuse is considered to be inconsequential.

Table IV-17 Phosphorus content
(Percent of Total Weight)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	76	0.025	0.033	0.030
Basic Sciences	101	0.026	0.002	0.030
Total Medical Center	177	0.026	0.002	0.029

Nitrogen Content

The nitrogen content of the refuse sampled is low (0.33 percent) but this compares with the low end of the values for municipal refuse that are shown in Table IV-18.

Table IV-18 Nitrogen content
(Percent of Total Weight)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	73	0.343	0.017	0.377
Basic Sciences	97	0.318	0.015	0.347
Total Medical Center	170	0.329	0.011	0.351

The nitrogen content is not considered important in incineration but could play a small role in composting or decomposition in landfills. The nitrogen content of this refuse is not considered significant.

Carbon Content

The high carbon content reflects itself in high BTU values and high volatile solids values. It also indicates a high organic content in the samples. These values would be lowered somewhat if metal and glass were added to the total from which the percentages were calculated. Comparing the values obtained in this study with those listed in Table IV-19 for municipal refuse shows this refuse to be on the high side.

Table IV-19 Carbon content
(Percent of Total Weight)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	76	45.840	0.334	46.508
Basic Sciences	101	43.149	0.277	43.699
Total Medical Center	177	44.304	0.236	44.767

Both incineration and biological decomposition can benefit from large carbon contents in the refuse. Carbon dioxide (CO_2) is the final product desired from the carbon in any waste.

Carbon-nitrogen or carbon-hydrogen ratios can be easily calculated from the data in these tables.

Hydrogen Content

The hydrogen content of this hospital's refuse is slightly above that expected in municipal refuse as shown in Table IV-20. Quantities of plastics larger than normally found in municipal refuse could explain part of this. A large hydrogen content is not considered bad and consequently the amount contained in this refuse should not be detrimental to any waste disposal practices.

Table IV-20 Hydrogen content
(Percent of Total Weight)

Location	No. of Observations	Mean	Standard Deviation	95% C.I.
Hospital	76	7.376	0.061	7.498
Basic Sciences	101	6.803	0.049	6.899
Total Medical Center	177	7.049	0.044	7.134

Table IV-21 Chemical test comparisons
(Ranges of values containing 68% of test means)

Chemical Test	Range	Comparison*	Comparison**
Moisture	4.0 - 6.5	8.8 - 575	15 - 35
Volatile Solids	95 - 98	53 - 95	50 - 65
Ash	2 - 5	4 - 38	-
B.T.U.	7,000 - 8,500	5,475 - 10,000	3,000 - 6,000
Sulfur	0.09 - 0.30	0.08 - 0.6	0.07 - 0.1
Phosphorus	0.009 - 0.040	0.12 - 0.70	-
Nitrogen	0.25 - 0.45	.3 - 1.74	0.2 - 1.5
Carbon	41 - 48	76 - 48	15 - 30
Hydrogen	6.3 - 7.7	4.2 - 6.4	2 - 5

* Ulmer, N. S., "Physical and Chemical Parameters and Methods for Solid Waste Characterization," Division of Research and Development, Open File Progress Report #RS-03-68-17 PHS - HEW, 1970.

** DeMarko, J. et al., Incinerator Guidelines - 1969, U. S. Dept. of Health, Education and Welfare, Public Health Service Publication No. 2012, p. 6.

V. BACTERIOLOGICAL AND VIROLOGICAL STUDIES

Introduction

The bacteriological studies were conducted in three phases; (1) a general approach at selected wastes to determine types and quantities of organisms present through the use of selective media and total population counts, (2) a more detailed examination for specific organisms from each of the generating units of the institution, and (3) a study of airborne bacteria that are generated during waste handling and pathways by which such bacteria can be disseminated within the hospital environment.

The virological studies consisted mainly of determining the length of time that viral agents persisted at room temperature on solid waste materials recovered from the Hospital, the efficiency of their recovery and some of the factors which might influence their survival or recovery. Isolation and identification of virus from raw refuse that had not been artifically contaminated was not attempted during this study.

PHASE 1 Bacteriological Studies

The increased production of solid waste has lead to an increased possibility of contamination of persons from pathogenic microorganisms in refuse. The presence of these organisms in the refuse has been verified and correlated with some of the current diseases of today (17,92). Some of the diseases that may be contacted through environmental association with the refuse from a hospital are: salmonellosis, tuberculosis, amebic dysentery, staphlococcal infections, streptococcal infections, typhoid, urinary tract infections, hepatitis, and diphtheria.

The increasing potential of infection by pathogenic microorganisms can only be controlled by proper environmental safeguards. Contact with the disease-related organisms in the refuse may result from direct handling of the wastes or indirect contact with some inanimate object that had been infected. It is important that a thorough investigation of waste be made and pathogens that are related to man and his diseases be identified. Their distribution throughout the institution and possible routes of communication should also be established.

Before this can be accomplished, it is necessary to provide some guide lines regarding what are organisms of importance and what means are available to correctly identify them. This will include, the sampling techniques that are presently being employed and the media that are used to culture these organisms.

The main objective is the correlation of the total bacterial count per gram of sample. This includes the total aerobic and anaerobic counts, plus the use of selective media for the counts for streptococci, staphlococci, coli, fungi, molds, and others. The endeavor today is to relate all of these pathogenic species (only a few species are pathogenic in each of the above groups) to their association with man and how, through environmental control, their virulence can be decreased.

Methods and Materials

All samples were taken from pre-determined stations established by other researching personnel. Each sample was checked for:

(1) Total Count - Standard Plate Count Agar, incubated at 37°C for 24-48 hours.

(2) Total Anaerobic Count - Standard Plate Count Agar, incubated at 37°C for 72-120 hours.

(3) Aerobic Sporeformers - Heat sample to 80°C for 30 minutes - use Nutrient Broth.

(4) Anaerobic Sporeformers - Heat sample to 80°C for 30 minutes - use Thioglycollate Broth.

(5) Coliform Count - Violet Red Bile Agar, MacConkey Agar

(6) Pathogenic Staphlococci - Mannitol Salt Agar

(7) Beta-Hemolytic Organisms - Blood Agar Plates

(8) Fungi - Cooke's Rose Bengal Agar

(9) Streptocci & Enterococci - Mitis Salivarius Agar

The Agars, Broths, Mediums and Preparations used to perform these analyses are listed in Appendix C.

Collection and Preparation of Samples

In the beginning of this study, all samples were taken from the incinerator room in the basement of the University Hospital. These samples were taken on a biased basis, avoiding all refuse that appeared to be an administrative level, and restricting the collection of samples to those of an obvious medical nature.

It was presumed that the refuse from the administrative offices was of a low microbial count and that it was important in the beginning to determine what were the real, potential pathogens that were to come from the medical wastes. In the latter part of this study sampling began on a total hospital basis to verify the previous assumption.

The collectors of the samples were always equipped with a disposable mask, rubber gloves, and a white laboratory coat. These precautions were taken because sorting through this refuse, the collector was subject to contamination from many infectious agents.

The sample was collected in large (10 gal.) plastic bags from the designated station and then tagged, identifying the station number, date, and the time the sample was picked up.

Each sample was picked on a random basis throughout the station area. The sample was then brought back to the laboratory for separation and grinding. It was also, necessary to sort from the refuse all plastic, such as utensils, plastic bags, syringes, etc., and metal items, such as scissors, needles, clamps, wire; because this material would break the grinders being used.

To decrease the initial bulk load on the smaller grinder, each specimen was pre-ground on a large Wisconsin grinder. The specimen was ground to the 2 mm size and then placed in sterilized metal container (1 pint) and identified by date, time and station number.

Analysis

Equipment:

(1) Dial-O-Gram Ohnus Balance, Weigh: 1600 gm capacity
(2) Beaker, Sterile, 50 ml
(3) Phosphate Peptone Buffer Solution
(4) Agar Plates (100 mm Diameter)
(5) Dilution Tubes (20 ml)
(6) Broth Tubes (20 ml)
(7) Incubator @ 37°C ± 0.5°C
(8) Brewer Anaerobic Jar
(9) Large, Glass Desiccator
(10) Small Candles
(11) Tube racks
(12) Sterile pipets - in 10 ml size - in 1 ml size (disposable)
(13) Sterile Cotton
(14) Bent Glass Rod

Steps in Analysis:

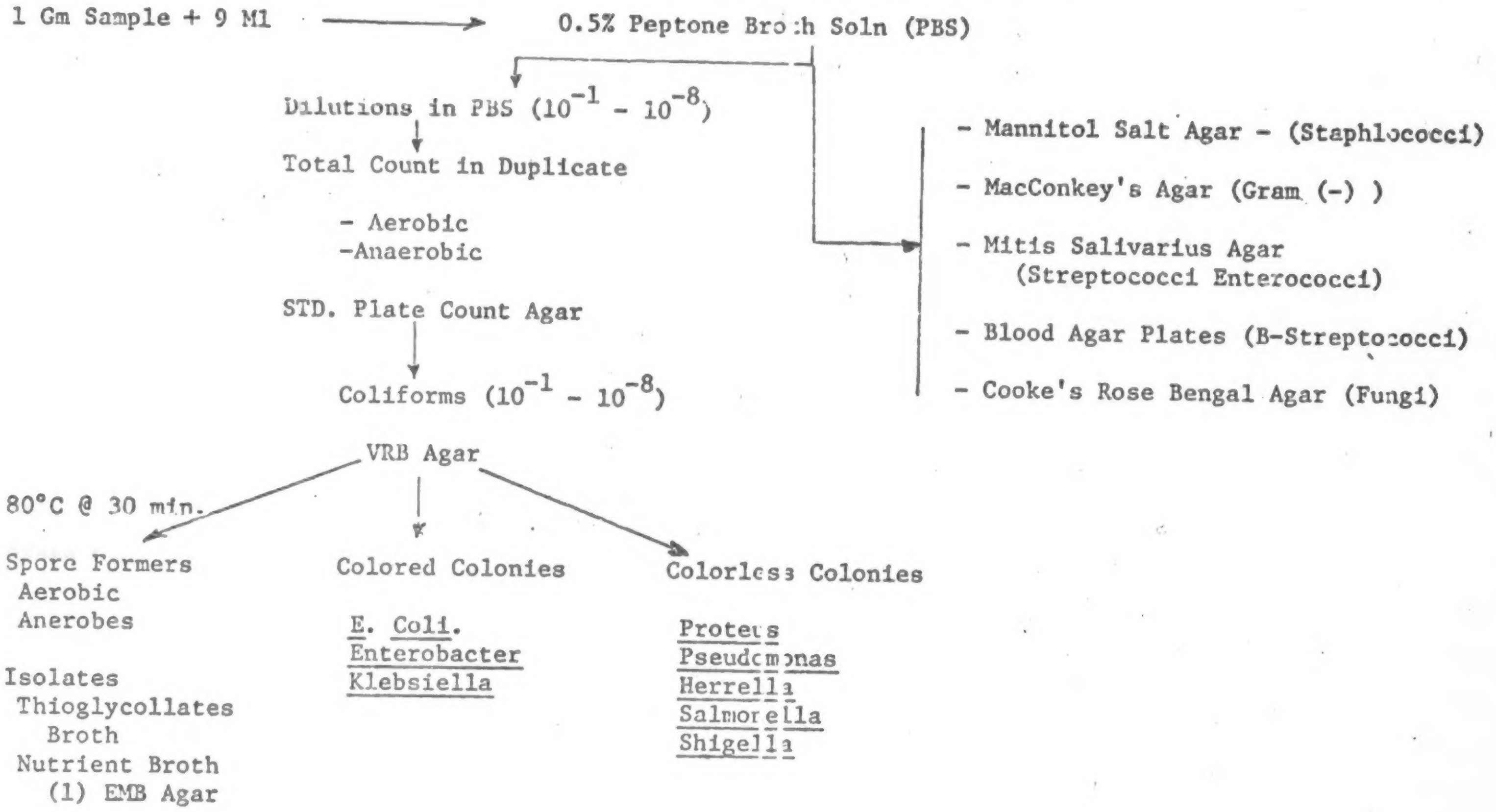
(1) All steps required strict aseptic conditions - Weigh 50 ml sterile beaker on balance.

(2) Add exactly 1 gm of ground sample with sterile tongs to beaker while still on balance.

(3) Add 9 ml of phosphate peptone buffer solution to beakered sample with a sterile pipet.

Figure V-1

FLOW DIAGRAM FOR BACTERIOLOGICAL EXAMINATION


1 Gm Sample + 9 Ml
0.5% Peptone Broth Soln (PBS)
Dilutions in PBS (10^{-1} - 10^{-8})
Total Count in Duplicate
- Aerobic
-Anaerobic
STD. Plate Count Agar
Coliforms (10^{-1} - 10^{-8})
VRB Agar
80°C @ 30 min.
Spore Formers
Aerobic
Anerobes
Isolates
Thioglycollates
Broth
Nutrient Broth
(1) EMB Agar
Colored Colonies
E. Coli.
Enterobacter
Klebsiella
Colorless Colonies
Proteus
Pseudomonas
Herrella
Salmorella
Shigella
- Mannitol Salt Agar - (Staphlococci)
- MacConkey's Agar (Gram (-))
- Mitis Salivarius Agar
(Streptococci Enterococci)
- Blood Agar Plates (B-Streptococci)
- Cooke's Rose Bengal Agar (Fungi)

(4) Follow this dilution scheme:

Original 1 gm + 19 ml = $10^{-1.3}$
2 ml ($10^{-1.3}$) + 8 ml = 10^{-2}
1 ml (10^{-2}) + 9 ml = 10^{-3}
1 ml (10^{-3}) + 9 ml = 10^{-4}
1 ml (10^{-4}) + 9 ml = 10^{-5}
1 ml (10^{-5}) + 9 ml = 10^{-6}
1 ml (10^{-6}) + 9 ml = 10^{-7}
1 ml (10^{-7}) + 9 ml = 10^{-8}

(5) Innoculation of Agar Plates and Broths - Each plate was innoculated with 0.1 ml of the dilutioned sample - and then spread evenly over the surface with a bent glass rod.

		Dilution Range	No. of Plates
(a)	Aerobic: Plate Count Agar	10^{-3} - 10^{-8}	2
(b)	Anerobic: Plate Count Agar	10^{-3} - 10^{-8}	2
(c)	Violet Red Bile Agar	10^{-1} - 10^{-6}	1 Each
(d)	MacConkey Agar	10^{-1} - 10^{-6}	1 Each
(e)	Mitis Salivarius Agar	10^{-1} - 10^{-6}	1 Each
(f)	Blood Agar	10^{-1} - 10^{-6}	1 Each
(g)	Cooke's Rose Bengal Agar	10^{-1} - 10^{-6}	1 Each
(h)	Mannitol Salt Agar	10^{-1} - 10^{-6}	1 Each

Then all dilutions were heated in water bath for 30 minutes @ 80-82°C and then inoculated 3/dilution into thioglycollate broth and nitrient broth.

(6) Incubation: All samples inverted during incubation

(a) "True" Aerobic Incubation - Plates placed in incubator

(b) Brewer Anaerobic Jar in incubator

(c) (d) (e) (f) (h) All incumbated "Microaerophillically" in glass disiccator in the presence of $CO_2 + O_2$. CO_2 environment is established by placing a small candle inside disiccator with plates in side, lighting it, close and incubate flame burns off a major portion of O_2 environment.

All samples incubated at 37°C ± 0.5°C for 24 hours except (6) Cooke's Rose Bengal Agar for fungi which is incubated @ 25°C ± 2°C, i. e. room temperature and read 48-72 hours.

(7) Counting - All colony counts were made on a Qubec Colony Counter. The only plates that were recorded were those in which the colonies numbered between 30-300.

(8) Computation of number of organisms per gram of refuse.

Results and Discussion

A complete test journal plus histograms for test bacterial counts are contained in Appendix C.

TEST #0

DATE: July 14, 1970 ORIGIN: Incinerator Room

PCA...AEROBIC:	10^{-4}: 4.4×10^{6}/gm mostly Bacillus, various types 5-10% Staphylococcus 5-10% Corynebacterium
PCA... ANAEROBIC	10^{-4}: 2.6×10^{6}/gm similar to aerobic plates
B.A.	10^{-4}: 5.1×10^{6}/gm most Bacillus, 3 Staphylococcus, 4 Corynebacterium no hemolytic colonies
MSA	10^{-4}: 9.0×10^{5}/gm Staphlococcus-like, overgrown with Bacillus
M-S	10^{-2}: 3.8×10^{4}/gm 10^{-1}: 12 possible mitis all Enterococcus,
VRB	10^{-2}: 2.5×10^{4}/gm .....coli 6.0×10^{4}/gm .....total no E. coli confirmed
MacC	10^{-2}: 2.7×10^{4}/gm .....coli 6.7×10^{4}/gm .....total also Streptococcus, no E. coli confirmed
CRB	$10^{-1.3}$: 1.2×10^{4}/gm molds: 1.0×10^{4}

yeast: 1.4×10^3

1.9×10^3 total of *fumigatus*, *Alternaria*, phycomycetes penicillin types, yellow *Aspergillus*

THIO. MPN: 1.5×10^4

N.B. MPN: 9.3×10^3

Station No. 0

Incinerator Room

The original sample taken from this station was biased for, it was compulsory to know which types of organisms were to be found in the "dirtiest" area of the hospital. As far as total count is concerned, *Bacillus* organisms were the most significant colonies present. *Staphylococcus* organisms comprised 5-10%, and *Corynebacterium* 5-10%.

Although there were many colonies of cocci-form bacteria present on the VRB and MacConkey Agars, none of these passed the confirmed test (BGBLB) for the presence of *E. coci*. CRB Agar presented a wide variety of molds and fungi, including phycomycetes, *Aspergillus*, and penicillin types.

Sporeformers from the thioglycollate and Nutrient Broth verified the high populations that are present in the refuse.

Actually because the sample was biased it can only be used as an indicator and not for total colony comparisons.

TEST #1

DATE: July 21, 1970 ORIGIN: Blood Bank

PCA...AEROBIC 10^{-3}: 9.9×10^5/gm

mostly mixed Bacillus, 5% Staphylococcus

PCA...ANAEROBIC	10^{-3}: 2.2×10^{5}/gm mostly Bacillus
B.A.	10^{-3}: 1.0×10^{6}/gm predominantly slow growing (48 hr.) small gram negative rods; dry, medium size, mat colonies, some with lacy margins, no hemolytic colonies.
MSA	10^{-2}: 1.3×10^{4}/gm Staphylococcus-like, overgrown with Bacillus
M-S	$10^{-1.3}$: 4.6×10^{3}/gm Enterococcus 1.4×10^{3}/gm S. mitis
VRB	$10^{-1.3}$: 2.6×10^{3}/gm.....coli 1.3×10^{4}/gm.....total *E. coli* confirmed (BGBLB)
MacC	$10^{-1.3}$: 4.8×10^{3}/gm.....coli 1.9×10^{4}/gm.....total *E. Coli* confirmed
CRB	$10^{-1.3}$: 8.4×10^{3}/gm molds: 4.4×10^{3} yeast: 4.0×10^{3} Aspergillus, yeasts, very varied green velvet
THIO.	MPN: 9.3×10^{5}/gm
N.B.	MPN: 4.3×10^{5}/gm

Station No. 1

Blood Bank

The station had a complete flora of the microorganisms under present observation. The most significant colonies were *Bacillus*, which predominated on the Aerobic, Anaerobic, B.A., MSA plates. On both the VRB and MacC plates, cocci-form were present and these were both positive for *E. coli* on BGBLB.

E. coli, Fecal coliform, should not be present in this area and further testing should decide whether this is a abnormal condition or if normal, what is its main route entry.

TEST #2

DATE: July 21, 1970 ORIGIN: Incinerator Room

PCA...AEROBIC	10^{-4}:	9.3×10^{6}/gm
PCA...ANAEROBIC	10^{-4}:	7.6×10^{6}/gm
		similar to aerobic growth
B.A.	10^{-4}:	7.7×10^{6}/gm
		predominantly B. *cereus*-like, hemolytic
MSA	10^{-3}:	3.3×10^{6}/gm all Staph. like
M-S	$10^{-1.3}$:	3.4×10^{3}/gm
		all enterococcus, no *mitis* seen
VRB	$10^{-1.3}$:	2.6×10^{3}/gm.....coli
		1.0×10^{4}/gm.....total
		E. coli confirmed (BGBLB)
MacC	$10^{-1.3}$:	2.6×10^{3}/gm.....coli
		1.1×10^{4}/gm.....total
		E. coli confirmed
CRB	$10^{-1.3}$:	3.6×10^{4}/gm
		molds: 2.2×10^{4} yeasts: 1.4×10^{4}
		Aspergillus, yeasts, very varied green velvet
THIO.	MPN:	4.3×10^{5}/gm
N.B.	MPN:	2.3×10^{5}/gm

Sample #2

Incinerator Room

All organisms found at this station are similar to the finding on Sample No. 0 on a previous date. The total count is approximately the same with the Bacillius organisms dominating the total count.

There is a good normal flora of staph., strep., and coliform microbes. The only variation from No. 0 sample is that this sample is positive for E. coli and this is quite understandable for this area.

CRB Agar had a high population of molds and yeasts.

TEST #3

DATE: July 24, 1970 ORIGIN: General Medicine (71)

PCA....AEROBIC	10^{-2}:	1.4×10^4/gm 5 bright yellow colonies, gram (-) rods 3 pale yellow colonies, gram (-) rods
PCA....ANAEROBIC	10^{-2}:	9.0×10^3/gm same as aerobic
B.A.	$10^{-1.3}$:	2.0×10^4/gm bright yellow colonies, few Strep., Corynebacterium, Bacillus, no hemolytic col.
MSA	$10^{-1.3}$:	1.0×10^3/gm all Staph. like
M-S	$10^{-1.3}$:	1.2×10^3/gm all enterococcus, no mitis seen
VRB	$10^{-1.3}$:	3.4×10^3/gm.....coli no coli confirmed
MacC	$10^{-1.3}$:	3.2×10^3/gm.....coli no coli confirmed

CRB	$10^{-1.3}$: no significant colonies
THIO.	MPN: 9.3×10^{2}/gm
N.B.	No growth

Sample #3

General Medicine (71)

The most significant colonies present were Bacillus and these accounted for approximately 90 percent of the total colonies seen. B.A. had a few no-Hemolytic Strep. and cocci-organisms. Staphylococcus colonies were dominating on the MSA. This sample was representative of the total spectrum of colonies under observation except for the CRB Agar which had no significant growth. This is a good indicator that the spore dispersal in the environment was quite low.

The total count is much lower than previous counts and this is due most probably to the disinfection procedures that are carried out.

This station is the adjacent hall to the Station (71) of the Sample No. 4. If these two samples are compared, it is worthy to note how the change occurred between them. This is another reason for more testing of Station (72).

TEST #4

DATE: July 24, 1970 ORIGIN: General Medicine (72)

PCA....AEROBIC	10^{-2}:	5.8×10^{4}/gm	all the same yeast
PCA....ANAEROBIC	10^{-2}:	6.3×10^{4}/gm	yeast
B.A.	10^{-2}:	8.9×10^{4}/gm	yeast, no hemolytic colonies
MSA	$10^{-1.3}$:	no Staph.-like	
M-S	$10^{-1.3}$:	no growth	
VRB	$10^{-1.3}$:	no growth	
MacC	$10^{-1.3}$:	no growth	

CRB	10^{-2}: 6.4×10^{4}/gm all yeast, no significant molds
THIO.	MPN: 4.0×10^{2}/gm
N.B.	No growth

Sample #4

General Medicine (72)

The only significant colonies that appeared in this test were yeast cultures. On the MSA, M-S, VRB, MacC, and Nutrient Broth there was no growth on the lowest ($10^{-1.3}$) dilution which is a good indicator that the sample was taken from an area in which there was little contamination. It is possible that in this hospital section that they have a high degree of aseptic conditions through the use of disinfectants and germicides.

It is also possible the sample was not representative. The sample was taken from the total section and ground according to established procedures.

A method to overcome this is to take several more samples from the section and to compare the results.

Conclusions

From the preceding analysis of the initial data, it is concluded that:

1. Bacillus organisms make up 80-90 percent of all microbes under observation.
2. Staphylococcus organisms comprise 5-10 percent of the population .
3. Streptococcus organisms comprised 5-10 perdent of the population.
4. Mannitol Salt Agar was not selective enough for Staphylococcus organisms, Bacillus grew too well, and a new Agar should be substituted, such as Staphylococcus 110 Agar.
5. The background count from the present 2-grinding technique is too high and a new method should be incorporated. A possible alternate is a Waring Blender.

6. Representative samples must be taken at least twice, or three times when possible, for good comparison of results.

PHASE 2 Bacteriological Studies

In order to assess the potential health hazard associated with refuse, a thorough bacterial examination of the refuse from each nursing station was necessary. This initially required a decision regarding what organisms would be of greatest concern in a general survey and by what methods they could be most readily identified.

The specific organisms chosen to be examined were Escherichia coli, Pseudomonas, fungi, yeasts, molds, staphylococci, and streptococci. Selective and differential medias for these organisms were chosen accordingly. Attempts were made to identify other dominant organisms. In addition to the specific counts, total colony counts of aerobic and anaerobic bacteria were performed.

The main objectives of this research project were (1) to determine what types of bacteria are most prevalent in the refuse (2) to obtain an estimation of the relative numbers of organisms, and (3) to investigate the possibility of existing trends between the numbers and types of organisms and the particular Hospital Units.

Collection of Samples

During the course of five months between September and February, 15 nursing stations at West Virginia University Hospital were each sampled three times. The total of 45 samples were taken at a random basis with four samples taken each week. The source of the refuse was from the waste receptacles in the bathroom and by the patient's bed. Several rooms from each wing were sampled in order to obtain a representative sample from the respective station.

The various types of stations included in the research were outpatient clinic, orthopedic, operating room, intensive care, general surgery, maternity, gynecology, pediatrics, general medicine, metabolic unit and emergency room.

The samples were usually collected between the hours of 1:00 P.M. and 3:00 P.M. Due to the nature of this work, the investigator was required to wear gloves and a white coat while collecting the samples.

Analysis

After the samples are collected, they are taken back to the laboratory for analysis. The laboratory used in this project is located in West Virginia University School of Engineering Building in Room B-33. The time interval between sampling and analysis never exceeded five hours. Aseptic techniques were stressed throughout all phases of the operation to minimize contamination and erroneous results.

All bacterial counts are listed in terms of bacterial counts per gram of sample. It should be noted that this number applies to the sample analyzed which includes only paper products and those items which the blender can accommodate. Other items in the refuse, such as plastics, metals, and fibrous materials had to be excluded from the analysis.

A. Media

1. Cooke Rose Bengal Agar (0703)
2. Blood Agar Base (0045)
3. MacConkey Agar (0075)
4. Mitis Salivarius Agar (0298)
5. Tellurite Glycine Agar (0617)
6. Plate Count Agar (0479)
7. Pseudosel Agar (11554)
8. Fluid Thioglycollate Medium (0256)
9. Lactose Broth
10. E E Broth
11. Brilliant Green Bile 2%
12. Azide Dextrose Broth
13. Phosphate Peptone Buffer Solution
14. Nutrient Agar

The following references were used for the selection of the proper media (110,111,112,113,114,94)

B. Equipment and Supplies

1. Brewer Anaerobic Jar
2. Disposable Agar Plates (100 mm diameter)
3. Dial-O-Gram Balance
4. Erlenmeyer Flasks, 500 ml
5. Dilution tubes (18 x 20 mm)
6. Broth tubes (20 ml)
7. Tube Racks
8. Incubator
9. Sterile Cotton
10. Large Plastic Bags
11. Water bath
12. Refrigerator
13. Sterile pipets, 1 ml and 10 ml
14. Waring Commercial Blender
15. Penicillin
16. Streptomycin
17. Kanamycin
18. Syringe (2 cc)
19. Gas Pak (R) BBL
20. Stock Cultures of Bacillus subtilis and E. coli.
21. Sterile Filter Paper Discs

C. Analysis Steps

1. Weigh 10 grams of sample (excluding metals, plastics and other material which is unacceptable to the blender.
2. Add 490 mls of sterile peptone buffer solution to a Waring Blender container.
3. Transfer the 10 gram sample to the blender container. (This yields a 1:50 dilution).
4. Blend the sample for approximately 60 seconds.
5. Follow this dilution scheme:

   5 mls of 1:50 dilution + 5 ml = 10^{-2}

   1 ml (10^{-2}) + 9 ml = 10^{-3}

   1 ml (10^{-3}) + 9 ml = 10^{-4}

   1 ml (10^{-4}) + 9 ml = 10^{-5}

6. Inoculation procedure:
   The lowest dilution plates are inoculated with 0.5 mls of the 1:50 dilution to yield a plate dilution factor of 10^{-2}. All other inoculations are made with 0.1 ml of the dilutions ranging from 10^{-2} to 10^{-5}. This will yield plate dilution factors of 10^{-3} to 10^{-6}. After inoculation, the liquid inoculum is spread evenly across the plates and allowed to dry.

	Medium	Dilution Range	Selectivity
a.	Cooke's Rose Bengal Agar	$10^{-2} - 10^{-6}$	molds & yeasts
b.	Mitis Salivarius Agar	$10^{-2} - 10^{-6}$	Streptococcus
c.	Pseudosel Agar	$10^{-2} - 10^{-6}$	Pseudomonas
d.	Blood Agar	$10^{-2} - 10^{-6}$	Not selective
e.	Blood Agar + Kanamycin (concentration 100 microgram/ml)	$10^{-2} - 10^{-3}$	Strict Anaerobes
f.	Anaerobic Plate Count Agar	$10^{-2} - 10^{-4}$	Not selective
g.	Aerobic Plate Count Agar	$10^{-2} - 10^{-6}$	Not selective
h.	Tellurite Glycine Agar	$10^{-2} - 10^{-6}$	Staphylococcus

7. All dilution tubes are then placed in the water bath at 80°C for 30 minutes. This is considered sufficient time to kill all vegetative bacterial cells leaving only the viable spores. Then 1 ml of each dilution is inoculated into the thioglycollate broth tubes using three tubes per dilution.

8. Incubation:

   All plates are inverted during incubation to prevent moisture from condensing and falling upon the medium.

   a. Anaerobic plate count agar plates and blood + kanamycin agar plates are first placed in Brewer Anaerobic Jar with an activated Gaspak and then into incubator at 37°C.

   b. Cooke's Rose Bengal Agar which is used for fungi is incubated at room temperature.

   c. All other media are placed in the incubator at a temperature of 37°C.

9. Colony Count Determination:

   Colonies were read on the Quebec Colony Counter. Most counts were recorded in the optimum counting range of 30 - 300 colonies. In some cases, however, other counts were used because optimum counts were not available - for example, less than 30 colonies on the lowest dilution and no colonies at higher dilutions. The Cooke's Rose Bengal Agar plates, the anaerobic plates and the Thioglycollate broth were read after five days. All other agar plates were read at two and five day intervals. Counts of spore forming organisms in the Thioglycollate broth were determined using a table of most probable numbers. (See Standard Methods for the Examination of Water and Wastewater, 1965, p. 608).

10. Computation of the number of organisms per gram of refuse. This computation is made by multiplying the number of colonies per plate times the plate dilution factor.

11. Test for Inhibitory Agents:
    Two pour plates were prepared using molten nutrient agar at 45°C and one drop of a young nutrient broth culture of E. coli and B. subtilis respectively. A sterile paper disc moisted in the 1:50 dilution was placed on each plate. The plates were examined and the inhibition of either bacterium was recorded as positive for antibacterial activity.

12. Identification tests
    - a. E. coli
        1. Typical pink colonies on MacConky agar.
        2. Gas production in lactose broth.
        3. Gas production in brilliant green bile broth.
    - b. Fecal Streptococcus
        1. Typical grey black colonies on Mitis Salivarious Agar.
        2. Growth with turbidity and mauve sediment in EVA broth.
        3. Gram positive cocci.
        4. Catalase negative.
        5. Ferment glucose in sealed thioglycollate medium.
        6. Growth at 10°C, 45°C, and in presence of 6.5% NaCl.
    - c. Staphylococcus aureus
        1. Large flat white, cream, or yellow colonies on plate count or blood agar or black colonies on tellurite glycine agar.
        2. Gram positive cocci.
        3. Catalase positive.
        4. Fermentation of glucose in a sealed thioglycollate medium.
        5. Coagulase positive by the slide test.
    - d. Candida albicans
        1. Budding yeasts.
        2. Produces pseudohyphae and chlamydiospores when growing on rice corn meal agar.
    - e. Pseudomonas aeruginosa
        1. Growth on media containing 0.03% cetrimide.
        2. Does not ferment glucose in a sealed thioglycollate medium.
        3. Produces cytochrome oxidase.
        4. Growth at 42°C.
        5. Produces blue green pigment.
    - f. Other organisms were identified as far as was practicable using generally recognized tests and criteria. The following references were used for identification (115,116,117,118,119).

Results and Discussion

Presentation of test data

Microbial counts of the various organisms in the refuse constituted the majority of the test data. These counts, expressed as the Log_{10} per gram of refuse, were recorded in Tables V-1 - V-4.

Table V-1 lists the total colony counts, as well as the counts of the specific organisms for which the selective medias were chosen. The following list provides the explanation of columns 1 - 11 in Table V-1.

Column

1. Number of the nursing station (Hospital units) sampled.
2. Number of the test at the respective stations.
3. Total bacterial count on the medium which gave the highest count.
4. The medium from which the total count was taken.
5. Coliform count on MacConkey Agar except at very low levels where growth in EE broth indicated a $\log_{10}$ count of 1.0.
6. Fecal Streptococcus on Mitis Salivarius Agar except at very low levels where growth in Azide Dextrose broth indicated a $\log_{10}$ count of 1.0.
7. Count of Staphylococcus aureus, on Blood Agar, Plate Count Agar, or Tellurite Glycine Agar.
8. Candida albicans count on Cooke Rose Bengal Agar.
9. Pseudomonas count on Pseudosel Agar.
10. Most Probable Number of heat resistant spores grown in fluid thioglycolate medium.
11. Antibacterial activity at a 1:50 dilution.

Table V-1 Total and individual counts (Log_{10})

Nursing Station (1)	Sample Number (2)	Total Count (3)	Medium (4)	Coliform Count (5)	Fecal *Strepto-coccus* Count (6)	*Staphylo-coccus* Count (7)	*Candida albicans* Count (8)	*Pseudo-monas* Count (9)	Spore Count (10)	Inhibitory Agent Test (11)
11	1	3.3	BA	1.0	<1.0	<2.0	<2.0	<2.0	<1.5	+
	2	3.0	BA	1.5	<1.0	<2.0	<2.0	<2.0	<1.5	+
	3	5.9	BA	<1.0	<1.0	4.0	<2.0	<2.0	<1.5	-
12	1	3.9	BA	<1.0	<1.0	3.2	<2.0	<2.0	3.9	+
	2	3.6	PCA	<1.0	<1.0	<2.0	<2.0	<2.0	<1.5	-
	3	2.6	PCA	<1.0	<1.0	2.5	<2.0	<2.0	<1.5	-
31	1	4.2	PCA(AN)	2.9	2.8	<2.0	<2.0	<2.0	2.0	-
	2	7.7	PCA	4.3	1.5	<6.0	4.5	<2.0	2.6	-
	3	6.7	BA	<1.0	<1.0	6.6	<3.0	<2.0	2.4	-
32	1	2.7	PCA	<1.0	<1.0	<2.0	<2.0	<2.0	2.0	-
	2	7.9	PCA	<1.0	1.5	<7.0	<2.6	<2.0	3.9	-
	3	7.2	PCA	1.5	<1.0	<2.0	<2.0	7.2	<1.5	+
36	1	2.5	PCA	<1.0	<1.0	<2.0	<2.0	<2.0	1.6	-
	2	<2.0	PCA	<1.0	<1.0	<2.0	<2.0	<2.0	<1.5	-
	3	3.5	PCA	<1.0	<1.0	2.7	<2.0	<2.0	<1.5	-
33	1	7.0	PCA	4.6	6.3	6.5	<2.0	2.6	2.0	-
	2	6.3	PCA	6.3	3.4	2.3	<2.0	<2.0	1.6	-
	3	6.9	PCA	6.8	4.3	<2.0	2.8	<2.0	<1.5	+
41	1	5.8	BA	<1.0	<1.0	5.7	<3.0	<2.0	<1.5	-
	2	5.7	BA	2.0	<1.0	2.7	<2.0	<2.0	1.6	-
	3	5.2	PCA	<1.0	<1.0	<2.0	<2.0	<2.0	<1.5	+

Table V-1 (Continued)

Nursing Station (1)	Sample Number (2)	Total Count (3)	Medium (4)	Coliform Count (5)	Fecal Streptococcus Count (6)	Staphylococcus Count (7)	Candida albicans Count (8)	Psuedomonas Count (9)	Spore Count (10)	Inhibitory Agent Test (11)
51	1	7.2	BA	<1.0	<1.0	7.1	<2.0	4.0	<1.5	+
	2	6.4	BA	1.5	1.5	<2.0	<2.0	<2.0	2.6	-
	3	5.4	BA	<1.0	4.9	<3.0	<2.0	<2.0	2.0	-
52	1	6.8	PCA	6.1	6.8	4.0	3.8	<2.0	3.9	-
	2	7.3	BA	1.5	1.5	<4.0	<2.0	<2.0	<1.5	-
	3	2.0	PCA	<1.0	<1.0	<2.0	<2.0	<2.0	<1.5	-
61	1	3.0	PCA	<1.0	<1.0	<2.0	<2.0	<2.0	<1.5	-
	2	7.8	BA	<1.0	7.1	<2.0	<2.0	<2.0	1.8	-
	3	5.3	PCA	<1.0	1.5	<3.0	<2.0	<2.0	2.0	-
62	1	8.1	BA	5.0	8.0	3.3	<2.0	<4.0	2.2	-
	2	7.7	PCA	7.7	1.5	<2.0	<2.0	<2.0	<1.5	-
	3	9.0	MS & MacC	8.6	7.0	5.7	<2.0	3.7	3.4	-
71	1	6.0	BA	<3.8	<1.0	<2.0	<2.0	3.9	2.0	-
	2	5.5	BA	<2.0	<1.0	<4.0	<2.0	<2.0	<1.5	+
	3	6.7	PCA(AN)	<4.0	<1.0	<2.0	<2.0	<2.0	2.0	-
72	1	6.4	PCA	3.4	<1.0	<2.0	<2.0	6.4	<1.5	-
	2	6.1	BA	<1.0	<1.0	<5.0	2.3	<2.0	1.6	-
	3	6.7	PCA	1.0-5.0	1.5	<3.0	<2.0	<4.0	<1.5	-

Table V-1 (Continued)

Nursing Station (1)	Sample Number (2)	Total Count (3)	Medium (4)	Coliform Count (5)	Fecal Strepto-coccus Count (6)	Staphylo-coccus Count (7)	Candida albicans Count (8)	Pseudo-monas Count (9)	Spore Count (10)	Inhibitory Agent Test (11)
82	1	7.7	BA	5.9	5.3	<1.0	<2.0	4.3	2.4	-
	2	8.5	PCA	5.4	5.3	<1.0	3.5	8.4	3.4	-
	3	4.5	PCA	<1.0	<1.0	1.1	<2.0	<2.0	1.6	-
83	1	6.1	BA	4.4	1.5	<1.0	<2.0	<2.0	2.0	-
	2	5.8	BA & PCA(AN)	1.5	<1.0	1.6	<2.0	<2.0	1.6	-
	3	2.7	PCA	<1.0	<1.0	<1.0	<2.0	<2.0	1.6	-

Table V-2 Microbial counts of organisms in Groups I-V (Log_{10})

Nursing Station	Sample Number	Group I Count	Group II Count	Group III Count	Group IV Count	Group V Count
Emergency 11	1	<1.0	<2.0	<2.0	<2.0	3.3
	2	1.5	<2.0	2.6	2.6	2.8
	3	<1.0	4.0	4.5	4.5	5.9
Outpatient 12	1	<1.0	3.2	<3.0	3.2	3.7
	2	<1.0	<2.0	3.6	3.6	<2.0
	3	<1.0	2.6	<2.0	2.6	<2.0
O. R. 36	1	<1.0	<2.0	<2.0	<2.0	2.5
	2	<1.0	<2.0	<2.0	<2.0	<2.0
	3	<1.0	2.7	<2.0	2.7	3.5
I.C.U. 33	1	6.3	6.5	<6.0	6.7	6.5
	2	6.3	2.3	<5.0	6.3	3.2
	3	6.8	2.8-4.0	6.1	6.9	<2.0
Surgical 31	1	3.2	<2.0	4.1	4.2	<2.0
	2	4.3	4.5-6.0	7.5	7.5	3.0
	3	<1.0	6.6	4.2	6.6	5.5
32	1	<1.0	<2.0	<2.0	<2.0	2.7
	2	1.5	<2.0	7.7	7.7	7.4
	3	1.5	7.2	<7.0	<7.0	<2.0

Table V-2 (Continued)

Nursing Station	Sample Number	Group I Count	Group II Count	Group III Count	Group IV Count	Group V Count
Surgical Cont.						
51	1	<1.0	7.1	2.3	7.1	6.5
	2	1.5	<2.0	6.4	6.4	5.3
	3	4.9	<3.0	4.8	5.2	5.0
52	1	6.8	4.2	3.5	6.8	<2.0
	2	1.5	<4.0	7.1	7.1	6.7
	3	<1.0	<2.0	<2.0	<2.0	2.0
61	1	<1.0	<2.0	<2.0	<2.0	3.0
	2	7.1	<2.0	7.2	7.4	7.5
	3	1.5	<3.0	5.3	5.3	<2.0
Medical						
71	1	3.8-4.6	3.9	4.6	4.8	6.0
	2	<1.0	<4.0	5.5	5.5	<2.0
	3	4.0	<2.0	6.7	6.7	4.0
72	1	3.4	6.4	2.3-5.0	3.4	<2.0
	2	<1.0	2.3	6.1	6.1	3.2
	3	1.0-5.0	<4.0	4.4	4.4	6.7
83	1	4.4	<5.0	5.8	5.9	5.7
	2	1.5	5.6	5.5	5.8	<2.0
	3	<1.0	<2.0	2.7	2.7	<2.0

Table V-2 (Continued)

Nursing Station	Sample Number	Group I Count	Group II Count	Group III Count	Group IV Count	Group V Count
Pediatrics 62	1	8.0	3.7	<7.0	8.0	6.0
	2	7.7	<2.0	<7.0	7.7	2.3
	3	8.6	5.7	8.7	9.0	6.0
Psychiatrics 82	1	6.0	4.3-6.0	6.9	6.9	7.6
	2	5.8	8.4	<5.0	5.8	7.8
	3	<1.0	4.1	3.7	4.3	4.1
Maternity 41	1	<1.0	5.7	5.0	5.7	4.7
	2	2.0	2.7	5.7	5.7	<2.0
	3	<1.0	<4.0	4.7	4.7	<5.1

Table V-3 Counts of specific organisms in Groups III and V

Nursing Station	Sample Number	Counts of Organisms Isolated in Group III	Counts of Organisms Isolated in Group V
12	1	. . . .	Bacillus sp. (3.7)
	2	Staphylococcus epidermidis (3.6)	. . . .
	3	. . . .	. . . .
11	1	. . . .	Xanthomonas (3.3)
	2	S. epidermidis (2.6)	Candida sp. (2.8), Enterobacter (2.0)
	3	S. epidermidis (4.0), Respiratory Streptococcus (4.1)	Corynebacterium sp. (5.9)
36	1	. . . .	. . . .
	2	. . . .	. . . .
	3	. . . .	Corynebacterium sp. (3.5)
33	1	. . . .	Corynebacterium like, catalase (-) (6.5)
	2	. . . .	Candida sp. (3.2)
	3	S. epidermidis (6.1), Torulopsis glabrata (3.1)	. . . .
31	1	Anaerobic cocci (4.1), Bacteroides (2.8)	. . . .
	2	S. epidermidis (6.3), Respiratory Strep. (7.4)	Proteus mirabilis (3.0)
	3	Torulopsis glabrata (4.2)	Micrococcus sp. (5.4), Lactic Strep. (4.9)
32	1	. . . .	. . . .
	2	S. epidermidis (7.7)	Micrococcus sp. (7.4), Unidentified Yeast (3.1)
	3	. . . .	. . . .

Table V-3 (Continued)

Nursing Station	Sample Number	Counts of Organisms Isolated in Group III	Counts of Organisms Isolated in Group V
51	1	Anaerobic Gram (+) Cocci (2.3)	*Corynebacterium sp*. (6.5)
	2	*S. epidermidis* (3.1), Respiratory *Strep*. (6.4)	Catalase (-) *Staph*. (5.1), *Aerococcus* (4.7)
	3	*S. epidermidis* (4.3), Respiratory *Strep*. (4.6)	*Micrococcus sp*. (5.0)
52	1	*Clostridium perfringens* (3.5)	. . . .
	2	Respiratory *Strep*. (7.1), *S. epidermidis* (4.6)	*Acinetobacter* (6.7), *Klebsiella* (4.2)
	3	. . . .	*Corynebacterium sp*. (2.0)
61	1	. . . .	*Corynebacterium sp*. (3.0)
	2	Respiratory *Strep*. (7.2), *Fusobacterium* (3.5)	*Micrococcus sp*. (7.0), *Corynebacterium* (7.3), *Candida sp*. (3.2)
	3	*S. epidermidis* (4.6), Respiratory *Strep*. (5.2)	. . . .
71	1	*S. epidermidis* (4.6)	Unidentified enterobacteria (5.5) *Micrococcus sp*. (5.8)
	2	*S. epidermidis* (5.5) Respiratory *Strep*. (3.8)	. . . .
	3	*Bacteroides* (5.9) Anaerobic non-sporeforming Gram (+) Rods (6.6), *S. epidermidis* (4.0)	*Corynebacterium* (4.0)

Table V-3 (Continued)

Nursing Station	Sample Number	Counts of Organisms Isolated in Group III	Counts of Organisms Isolated in Group V
41	1	Anaerobic Gram (+) Cocci (4.5) Respiratory *Strep*. (4.9)	Lactic *Strep*. (4.6) Unidentified Yeast (3.9)
	2	Respiratory *Strep*. (5.7) *Bacteroides* (3.1)	. . . .
	3	*S. epidermidis* (4.7)	*Bacillus sp*. (5.1), *Penicillium* (3.1)

Table V-3 (Continued)

Nursing Station	Sample Number	Counts of Organisms Isolated in Group III	Counts of Organisms Isolated in Group V
72	1	S. epidermidis (2.3)	. . . .
	2	S. epidermidis (3.9), Respiratory Strep. (3.4)	Lactobacillus (3.2)
	3	S. epidermidis (4.4)	Alcaligenes (6.1), Pseudomonas sp. (6.0) Unidentified Enterobacteria (5.9) Xanthomonas (5.8), Corynebacterium sp. (6.1), Large Pleomorphic Gram (+) Rods (6.0)
83	1	S. epidermidis (5.8), Bacteroides (4.5)	Corynebacterium sp. (5.7), Candida sp. (3.0), Lactobacillus (2.8)
	2	Bacteroides (4.4), Anaerobic nonsporeforming Gram (+) Rods (5.5) Respiratory Strep. (3.2)	. . . .
	3	S. epidermidis (2.7)	. . . .
62	1	. . . .	Catalase (-) Staphylococcus (4.8) Pseudomonas sp. (6.0)
	2	. . . .	Proteus vulgaris (2.3)
	3	Respiratory Strep. (8.7)	Catalase (-) Staphylococcus (6.0)
82	1	S. epidermidis (6.9)	Corynebacterium sp. (7.4), Lactic Strep. (7.3), Unidentified Yeasts (2.0)
	2	. . . .	Proteus mirabilis (7.8)
	3	Respiratory Strep. (3.7)	Acinetobacter (3.5), Pseudomonas sp. (3.9)

Table V-4 Geometric mean of bacterial counts (Log_{10})

Nursing Station	Total Count	Group I Count	Group II Count	Group III Count	Group IV Count	Group V Count
11	4.1	1.0	2.7	3.0	3.0	4.0
12	3.4	<1.0	2.6	2.9	3.1	2.6
36	2.5	<1.0	2.2	<2.0	2.2	2.7
33	6.7	6.5	4.3	5.5	6.6	3.9
31	6.2	2.8	4.4	5.3	6.1	3.5
32	5.9	1.3	4.6	4.8	5.5	3.7
51	6.3	2.5	4.0	4.5	6.2	5.6
52	5.4	3.1	3.1	4.2	5.3	3.6
61	5.4	3.2	<2.0	4.8	4.9	4.2
71	6.1	2.9	2.9	5.6	5.7	3.3
72	6.4	3.4	4.4	4.3	4.6	4.0
83	4.8	2.3	3.8	4.7	4.8	3.2
62	8.3	8.1	3.8	7.6	8.2	4.8
82	7.0	4.3	6.1	5.3	5.7	6.5
41	5.6	1.3	4.2	5.1	5.4	2.9

In order to facilitate interpretation of data, all identified organisms were placed in one of five groups. The data contained in Table V-2 represents the summation of counts of the individual organisms in each group. The criteria for the grouping of the organisms is as follows:

Group I contains the combined counts of the Coliform and fecal Streptococcus organisms. This group is designed to serve as an index of fecal contamination.

Group II contains the combined counts of Staphylococcus aureus, Candida albicans, and Pseudomonas. These organisms are known to be secondary pathogens. They will be discussed in greater detail later in this paper.

Group III contains the combined counts of all microorganisms known to be of human origin other than Staphylococcus aureus and Candida albicans.

Group IV contains the total of all the identified microorganisms which are known to be of human origin. This important group actually is the summation of Group III and the counts of Staphylococcus aureus and Candida albicans. This group is useful in that it serves as an indicator of human contamination.

Group V contains all organisms which are not necessarily of human origin, that is they are commonly found outside the human body. For example, many of these bacteria are commonly found in the soil.

Table V-3 is designed to list the individual species of bacteria in Groups III and V and their respective counts. It gives an indication of the rather sporadic frequency with which the various organisms appear in the different samples.

Table V-4 lists the geometric means of counts of organisms in Groups I - IV for each station. These numbers represent the maximum possible values. For example, in many cases at least one of the three counts had to be recorded as a number less than two. This was the limit of the sensitivity of our test. In these cases, the number two would be used in the computation of the mean value. Another problem arises when an organism similar in appearance to the one to be counted, occurs in large numbers. This makes counting of the specific organism virtually impossible. All that can be recorded is that its colony count is something less than the total count on the plate. When this occurred, the uncertain number was ignored in the computation of the sample mean.

Figures C-7 - C-12 in Appendix C are histograms which provide a graphic presentation of the data from Table V-4. They present a visual comparison of microbial counts of the 15 respective nursing stations involved in this study.

See Appendix C for a list of nursing stations, their functions, and the dates at which the samples were taken.

Total Counts

The repetitive sampling of the 15 nursing stations makes possible some interesting comparisons. As expected, many of the stations had total bacterial counts which varied over several orders of magnitude. This could have been due to a number of factors. Probably the most important variable is the condition of the patient in the rooms. Sometimes the period of time which elapsed between two repetitive tests was several weeks. During this period of time, one may expect a complete turnover of patients.

Another factor is simply that the degree of contamination varies from day to day, even among the same patients. This is probably due to variable personal habits.

A third factor to be considered is that the total counts do not represent the entire population in the refuse but only the bacterial population in the sample. It should be mentioned again that the sample tested contained only those materials which were acceptable to the blender. Unfortunately, some apparently grossly contaminated items necessarily had to be omitted from the analysis.

In spite of these variables which would tend to bring about differences in total counts, one should note that seven of the fifteen stations Numbers 12, 33, 41, 51, 62, 71, and 72 exhibited three total counts which differed from each other by a factor of less than 100. There were several stations among the others which had two total counts that were very similar.

Two explanations may be postulated to account for the low variability among the three total counts per station. One would be the similarities in the condition and type of the patients at the particular stations. For example, the poor condition of patients confined to Intensive Care Unit, Station 33, would suggest the appearance of a high degree of contamination in the refuse. Likewise, in Pediatrics, Station 62, one would expect a high degree of fecal contamination from soiled disposable diapers. This naturally leads to very high total colony counts.

Another explanation could be based upon the methods by which the wastes are handled. Thus, one would expect consecutively low bacterial counts from stations which segregated their contaminated waste from the uncontaminated. Such is the case with Operating Room, Station 36. In this case only the uncontaminated waste was available to be sampled. For this reason, Station 36 had the lowest total count. Another important factor would be that at this station, there is much greater demand for an aseptic environment.

Stations 12 and 11 offered the second and third lowest total counts, respectively. Emergency room, Station 11, is frequented by a great variety of people and one might expect higher total counts. However, the presence of agents inhibitory to bacterial growth in two of the three samples taken might account for this low population. Outpatient Clinic, Station 12, offers many of the same possibilities for contamination as Emergency Room. The low counts are probably due to diluting effects of large quantities of apparently uncontaminated paper products. The presence of inhibitory agents is also a plausible explanation.

Stations 33 and 62 had the highest total colony counts. Reference has previously been made to the possible explanations. Station 82 had two very high total counts. This is a psychiatric ward. The reasons for the high counts are not readily apparent but differences in personal hygiene may partially be responsible.

See Figure C-7 for a graphic comparison of total colony counts.

Coliform and Fecal Streptococcus Counts

Coliform counts were highest at stations 62, 33, and 82, respectively. The explantions for these high counts are the same as those given for the high total colony count. Coliform counts indicate fecal contamination. These counts should serve as an index to assess the hazard of pathogenic enteric bacteria such as Shigella and Salmonella typhosa. Fecal Streptococcus, as expected, occurred with approximately the same frequency as the coliforms but at lower growth levels.

Group I Counts

Group I consists of the combined counts of coliform and fecal Streptococcus. Figure C-8 illustrates the significant fecal contamination in the refuse of stations 62, 33, and 82. Also illustrated is the notable absence of these organisms at stations 11, 12, and 36.

This absence might be explained by the fact that these stations have no living quarters; and, therefore, the probability of this type of contamination is somewhat reduced.

Staphylococcus Aureus Counts

Staphylococcus aureus is one of the most important pathogens in nosocomial cross infection. It is easily spread in dust particles. Therefore, its presence in refuse is particularly significant. It is notorius as the cause of suppurative (pus forming) condition; boils, carbuncles, infantile impetigo, and internal abscesses in men and women.

S. aureus appeared at all stations except stations 32, 61, 71, and 72. The greatest frequency of occurrence (two of three samples) occurred at stations 62, 41, 33 and 12. The highest average count occurred at station 62 with the highest single S. aureus count appearing at station 51.

Candida Albicans Counts

Candida albicans is a pathogenic fungus which is commonly found on the skin, on oral or vaginal mucous membranes or in the feces of normal individuals. This species can cause a number of serious infections in man, especially of mucous membranes (thrush and vulvovaginitis), the skin (cutaneous candidiasis) and lungs (pulmonary candidiasis).

This organism was found at stations 31, 33, 52, 72 and 82. Its frequency of appearance was quite low (one of three samples). The highest count was observed at station 31.

Pseudomonas Count

The genus Pseudomonas contains several species which are responsible for a number of types of infections. They cause urinary tract infections, as well as secondary infections of burn patients. They can also be responsible for outbreaks of diarrhea in children's wards.

The greatest frequency of occurrence (two of three samples) was at station 82. Pseudomonas also appeared at stations 32, 33, 51, 62, 71 and 72. Station 82 had the highest average, as well as individual counts of Pseudomonas.

Group II Counts

Group II consists of the combined counts of S. aureus, Candida albicans, and Pseudomonas. These three organisms are "opportunists;" that is, they take advantage of a patient whose resistance to infection has been lowered by some other illness.

From Figure C-9, it will be observed that the Group II counts cover a broad spectrum and are evenly distributed among the 15 nursing stations. It is interesting to note that the only station at which these microorganisms failed to be detected was station 61. Station 36 also exhibited a very low count. One of the three samples taken from this station contained these organisms in very low numbers. On the other end of the spectrum are the counts from station 82. This station had the highest single count, as well as the largest average count of Pseudomonas.

Group III Counts

Group III contains all organisms considered to be of human origin, excluding two of the more common species - S. aureus and Candida albicans. The exception of these two organisms is designed to give an indication of the magnitude of the count contributed by less notorious organisms of human origin.

The only station at which this organism failed to appear was station 36. Station 12 also exhibited a very low count of these bacteria. All of the stations showed a significantly high count in at least one of the three samples taken. The highest individual count came from station 62.

Group IV Counts

Group IV is the most important group because it contains the combined counts of all organisms of human origin. It, therefore, serves as an indicator of human contamination. The various species of these organisms are found in Table V-3.

From Figure C-11 we see that at least some of these organisms were detected at all 15 nursing stations. The lowest count by far was observed at station 36. The organisms were detected in only one of the three samples taken from this station. Stations 11 and 12 showed low counts relative to those of the remaining stations. The greatest average, as well as single count of these microorganisms, occurred at station 62. The counts from all three of the samples taken at this station were greater than any of those taken from the other stations. Other stations exhibiting high counts were stations 33, 31, 51, 71, and 82.

Group V Counts

Group V consists of bacteria which are not necessarily of human origin. Therefore, the detection of these organisms does not imply any human contamination. The various species of these identified bacteria are enumerated in Table V-3. The inclusion of this group in the report is intended to give some indication of the fraction of the total colony counts contributed by organisms of non-human origin.

From Figure C-12 it can be seen that bacteria from this group appeared at all 15 nursing stations. The two lowest counts were observed in the samples taken from stations 12 and 36. The highest count was observed at station 82. Station 51 also had a high number of these organisms in its refuse.

Sporeforming Organisms Count

Bacterial spores are partially resistant to heating and drying and other methods of sterilization. Therefore, their relative abundance and distribution in the hospital would be of concern with regard to sterilization procedures.

The only station which failed to yield any sporeforming organisms was station 11. Stations 12, 36, 41, 52, and 72 also showed a low frequency (one out of three samples). Stations 82, 31, and 83 showed the highest frequency of sporeforming organisms. Station 82 had the highest average spore count and also the highest individual count.

Inhibitory Agents

Inhibitory agents such as bactericides, fungicides and antibiotics will occasionally be discarded into the refuse. The extent of the antibacterial action that it exerts would depend upon how thoroughly it is combined with the refuse. During the blending phase of the analysis, inhibitors are completely mixed. Therefore, the presence of an inhibitory agent might result in a count substantially lower than what is actually present in the refuse container.

Seven of the 15 stations at one time had refuse which contained inhibitory agents. The only station which exhibited this twice was Emergency Room. There appears to be no significant difference between counts (total and of likely human origin) between samples with and without inhibition. In one case, the inhibition was almost certainly due to the high count of Pseudomonas aeruginosa which is known to produce an antibiotic.

Conclusions

From the preceeding analysis of the data, we make the following general conclusions:

1. Pathogenic bacteria can be present in hospital refuse in significantly high concentrations. These concentrations may be much higher if the organisms are located where organic substrate is present. Also, the additional time between collection and incineration may allow further multiplication of the microorganisms leading to higher counts than those observed in the tests.
2. Trends do exist between the number of microorganisms present and the respective nursing stations. From the previous discussion of results, it was observed that certain stations, such as station 36, exhibited consecutively low bacterial counts in their refuse. Other stations produced consistently high counts such as stations 33, 62, and 82.
3. Certain types of bacteria are more prevalent in the refuse of some stations than others. This is most probably due to source and type of waste generated.

From Table V-1 and Figures C-7 - C-11, we draw the following specific conclusions:

1. S. aureus is by far the most predominant pathogen in the refuse. It is most unfortunate that the true numbers of this pathogen were often unobtainable due to the high growth of S. epidermidis on the selective agar plates.
2. The high coliform counts from stations 33 and 62 suggest that these stations would be the ones most likely to generate refuse containing enteric pathogens.
3. Sporeforming organisms are not present in sufficient numbers to pose a potential hazard providing that the accepted methods of sterilization are utilized.

4. The substantial number of organisms of human origin relative to those not of human origin would suggest the presence of some of the more virulent pathogenic bacteria and viruses living on the refuse in undetected numbers.
5. The recurring high counts of organisms in groups I - V in the refuse of stations 33, 62 and 82 would indicate that the refuse from these stations is the most likely to be contaminated by pathogenic microorganisms.

PHASE 3 Bacteriological Studies

There is a growing concern about the microbiological hazards of hospital refuse handling. Several authors have expressed their concern about the possibility of pathogenic organisms escaping from the hospital refuse chute and into the hallways. At the present time there have been only a few studies of airborne bacteria from hospital refuse. It is difficult to compare data from different studies because there are no standard methods for air sampling of this type.

Many of the articles on this subject make recommendations to minimize the problem of air contamination from the refuse chute. Several of them are summarized below:

1. Design the chute so that air cannot back up into the hospital corridors and provide doors which are leakproof.
2. Separate refuse so that only uncontaminated materials are thrown into the chute.
3. Empty the chute often enough so that refuse does not back up in the chute and block the doors.
4. Autoclave all materials before they are thrown into the chute.
5. Increase the use of plastic liners for cans so that the refuse is wrapped before being thrown into the chute.
6. Wash the chute regularly with antiseptic.
7. Minimize waste transfer operations.

Some of these methods are very difficult and would be impractical because of the high cost involved. One of the easier methods to implement is the plastic bag system. The use of plastic liners to minimize air contamination has become increasingly popular and there are several articles in hospital magazines which make unsubstantiated claims of effectiveness.

The purpose of this phase was to evaluate the sanitation of a hospital refuse chute with respect to airborne bacteria. The study attempted to measure the dispersal of viable airborne bacteria from the handling of refuse in the chute closet area. The effect of wrapping the refuse in bags was evaluated. Recommendations were made for methods to reduce the number of bacteria escaping from the chute and entering the hallways.

Solid Waste Handling

The hospital studied had a refuse chute which is 118.2 feet high and 24 inches in diameter. The total volume is 372 feet. The effective storage capacity is the volume up to the bottom of the first door which is 69.4 cubic feet. The chute is fitted at the top (eighth floor) with a sprinkler head which is used for fire control and for washing twice a week with an antiseptic solution. The chute has a door on each floor and empties into a closet provided with a metal door.

The refuse is emptied from the chute into a cart and is taken to a larger room which contains a multi-chambered incinerator. The larger room has a fan mounted on one wall which draws air from the hallway into the room. All or part of the air drawn into the room can follow these alternative pathways; 1 - pass through the primary combustion chamber, 2 - pass through the chimney damper, 3 - go up the chute closet vent, 4 - go up the chute itself, or 5 - out the door and vent to the hallway. The fan is usually on when someone is in the room.

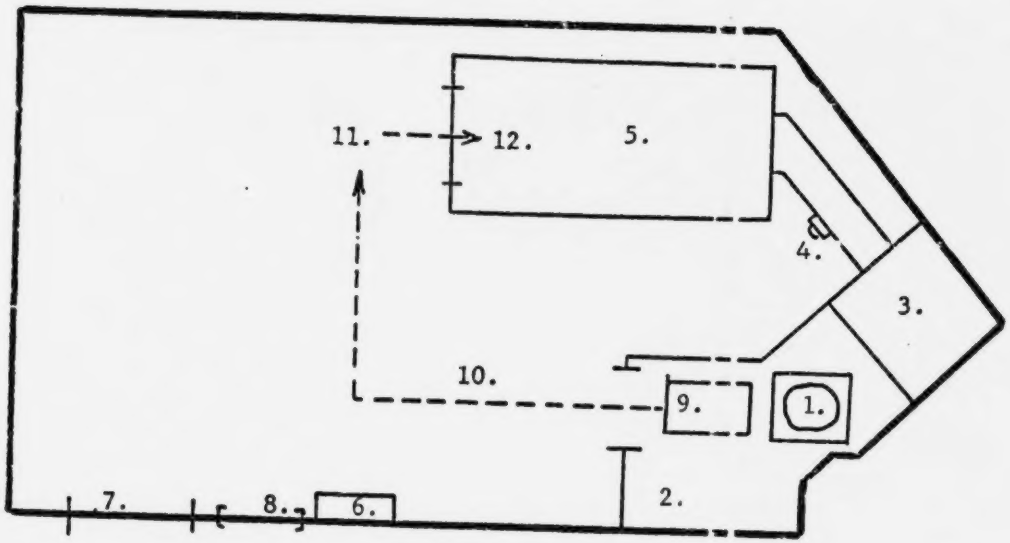
In practice the refuse stays in the chute several hours at a time and has occasionally backed up as far as the third floor of the hospital according to the engineering staff of the hospital. This refuse is comprised of "floor refuse" such as paper, trash, and food wastes from the wards, pathological wastes, including dressings, syringes, and other disposable equipment; and some kitchen wastes. It is of interest that the first door immediately above the chute closet is the door to the kitchen. The refuse packs against this door and could be a source of food contamination in the kitchen. Air temperatures in the chute closet averaged in the low 80's and the relative humidity was in the 55-65 percent range.

Methods and Materials

A. Bacterial Studies

Quantitative sampling of airborne bacteria was carried out with Andersen samplers (93) and petri plates made with Difco Blood Agar Base mixed with 5 percent defibrinated sheep blood (94). Samples were taken for periods of one minute at a sampling rate of 1.0 cubic ft/min. After exposure, the plates were incubated aerobically at 35°C for 24 hours and the number of colonies per plate were counted with a Quebec colony counter. This resulted in a count of aerobic organisms/cu.ft. which was broken down into six aerodynamic sizes. According to the original research carried out on the Andersen sampler (93), the instrument has essentially no loss due to adherance to the walls, and captures essentially all of the organisms by the sixth stage ($>$ 99 percent).

According to the Difco Manual (94) the blood agar media will grow most bacteria including many fastidious pathogenic organisms. The bacteria usually grow luxuriantly, and the hemolytic types exhibit clear zones of hemolysis. Previous research (95) has shown that the total anaerobic airborne bacteria constitute a very small part of the total count and may be disregarded in studies of this type.



1. Refuse chute
2. Chute closet
3. Chimney
4. Chimney damper
5. Incinerator
6. Fan
7. Door to hallway
8. Vent to hallway
9. Cart sampling point
10. Push cart to incinerator
11. Empty cart on floor
12. Sweep refuse into incinerator

Figure V-2 Incinerator and Chute Closet Area

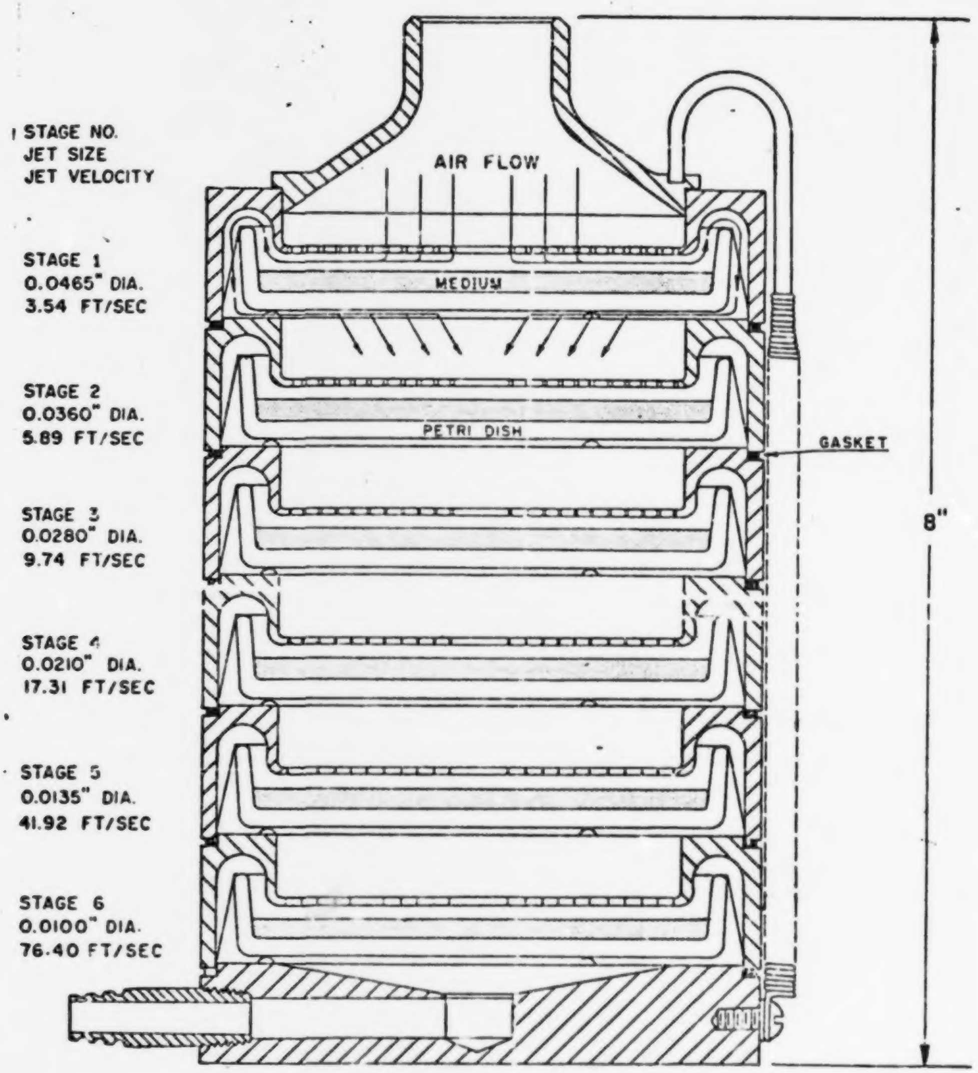

STAGE NO.
JET SIZE
JET VELOCITY
AIR FLOW
STAGE 1
0.0465" DIA.
3.54 FT/SEC
MEDIUM
STAGE 2
0.0360" DIA.
5.89 FT/SEC
PETRI DISH
GASKET
STAGE 3
0.0280" DIA.
9.74 FT/SEC
8"
STAGE 4
0.0210" DIA.
17.31 FT/SEC
STAGE 5
0.0135" DIA.
41.92 FT/SEC
STAGE 6
0.0100" DIA.
76.40 FT/SEC

Figure V-3 Andersen Sieve Sampler

Samples were taken on random days of the week and at random times of the day between 8:00 A.M. and 5:00 P.M. The sampler was placed at a height of three feet and a distance of four feet from the chute in the chute closet. Samples were taken of loose refuse and of refuse wrapped in plastic bags as it was transferred from the chute to the trash cart.

Results and Discussion

The results of these tests are expressed as the number of colonies of bacteria per cubic foot of air samples and are shown on Tables V-5 and V-6 for loose and bagged refuse respectively.

Air Movement Studies

The air moving out of the chute into the hallway was measured with an Alnor velometer, type 3002. This instrument measures the velocity and pressure of air with a mechanical system utilizing an aluminum vane in a calibrated air chamber. Velocities are in feet per minute and the area of the opening is in square feet. The air flows computed are given in cubic feet per minute.

The area of the chute opening is 1.54 feet x 1.54 feet = 2.37 feet^2, when the chute door is wide open. Tests were made on the flow from the chute door while no other chute doors were open with the following average values:

Floor Number 8 - 55 ft/min or 124 cubic ft/min
7 - 50 " 111 "
6 - 40 " 95 "
5 - 40 " 95 "
4 - 40 " 95 "

These values fluctuated approximately ± 5 ft/min when all other chute doors were closed.

Table V-5 Airborne bacterial counts from loose refuse
(No. Colonies/cu.ft.)

	Stage Number						
Ordered sample number	1	2	3	4	5	6	Total
1	5	4	1	3	3	1	17
2	23	4	4	0	0	1	32
3	22	11	9	6	1	0	49
4	14	14	13	8	1	1	51
5	27	6	9	10	1	1	54
6	23	15	10	7	4	0	59
7	44	7	5	4	4	0	64
8	23	15	13	9	5	0	65
9	29	13	14	5	2	2	65
10	35	17	13	1	1	0	67
11	34	13	9	8	2	3	69
12	31	14	9	3	5	0	70
13	31	21	11	7	3	2	75
14	34	15	12	12	3	0	76
15	36	23	10	4	4	0	77
16	33	19	16	4	5	0	77
17	30	15	14	13	7	1	80
18	38	21	16	9	3	0	87
19	28	23	31	4	3	0	89
20	39	16	26	10	0	1	92
21	38	26	11	15	5	1	96
22	47	24	13	9	2	3	98
23	51	23	14	13	2	1	104
24	69	18	14	6	1	0	108
25	42	22	20	18	9	1	112
26	57	24	23	13	2	0	119
27	54	33	33	21	3	1	145
28	84	40	31	16	4	0	175
29	136	73	51	24	7	0	291
30	192	68	81	46	12	3	402

Table V-6 Airborne bacterial counts from bagged refuse
(No. Colonies/cu.ft.)

Ordered sample number	Stage Number						
	1	2	3	4	5	6	Total
1	1	1	1	0	0	0	3
2	2	1	0	0	0	0	3
3	2	1	1	0	0	0	4
4	3	0	0	0	0	1	4
5	1	3	1	0	0	0	5
6	3	2	0	0	0	0	5
7	1	1	1	0	1	2	6
8	2	1	1	1	0	1	6
9	4	0	1	1	0	0	6
10	3	1	0	1	2	0	7
11	2	1	2	0	2	0	7
12	4	1	1	1	1	0	8
13	3	2	0	0	2	1	8
14	3	1	2	0	1	1	8
15	3	3	1	1	0	1	9
16	4	2	2	1	0	0	9
17	6	1	0	0	1	1	9
18	4	2	2	0	1	0	9
19	2	2	4	2	0	0	10
20	7	2	1	0	0	0	10
21	8	1	1	0	0	0	10
22	3	1	3	0	3	1	11
23	9	0	1	0	0	1	11
24	7	1	1	2	0	0	11
25	6	1	3	1	0	1	12
26	9	2	0	1	0	0	12
27	10	1	1	1	0	0	13
28	9	1	1	0	2	1	14
29	6	2	4	3	2	5	22
30	20	2	2	1	2	1	29

Next, the flow of air was determined when other chute doors were open. The velometer was placed at the 6th floor chute door and the 4th floor chute door was opened. The rate of flow at the 6th floor immediately increased to 150 ft/min or 355 cubic ft/min.

Then, the fourth floor chute door was closed and the eighth floor chute door was opened. The velometer immediately pinned to the zero mark.

From these results it appears that the air in the chute will exhaust onto the highest floor level available. If only one door is open, the flow of air is limited to 55 feet/min or less. The magnitude of flow is usually greater on the upper floors. For example, when the sampler was placed on the eighth floor chute door and the sixth floor chute door was opened, the flow through the chute door was greater than 300 feet/min. or 710 cubic feet/min.

By comparison, the Hurst study (34) found that when one of the upper floor chute doors in a 16-story hospital was opened, as much as 30 to 60 cubic feet of air was released in five to ten seconds. This is approximately the same flow as in this hospital.

Statistical methods were used to compare the effects of loose and bagged refuse on dispersal of airborne bacteria. An examination of the frequency distribution of total colonies per cubic foot (Table V-7) indicates that the data is essentially normally distributed. Thus, a parametric test of the mean is justified. In this case, the variances of the two populations are considerably different. The ordinary "t" test will tolerate considerable inequality between the two population variances without appreciable change in the probabilities of errors of Type I and II (96). However, Cochran and Cox suggest a modified "t" test (97) which takes into account the differences in variance.

The result of this test indicates that the mean population of airborne bacteria from loose refuse and bagged refuse, under the conditions of the experiment, are

Table V-7 Frequency distribution of total colonies
of bagged and loose refuse

Frequency distribution of total colonies - Loose Refuse

Range #Colonies	Frequency	Relative Frequency
0-25	1	0.033
25-50	2	0.067
50-75	9	0.300
75-100	10	0.333
100-125	4	0.133
125-150	1	0.033
150-200	1	0.033
200-300	1	0.033
300-350	1	0.033
	30	1.000

Frequency distribution of total colonies - Bagged refuse

Range #Colonies	Frequency	Relative Frequency
0-2	0	0.00
2-4	2	0.067
4-6	4	0.133
6-8	5	0.167
8-10	7	0.233
10-12	6	0.200
12-14	3	0.100
14-16	1	0.033
16-25	1	0.033
25-30	1	0.033
	30	1.000

not equal. We accept the alternative hypothesis which may be stated as: we are 99 percent certain that refuse wrapped in bags generates fewer airborne bacteria than loose refuse, under the conditions of the experiment. Presumably, the difference between the two systems would be even greater if the refuse was wrapped in completely leakproof bags.

An examination of the size distribution of the samples (Table V-8) indicates that there is a wide variation in the magnitude of bacteria in all size classifications. The majority of the bacteria in all samples were concentrated in the larger particle size ranges (Figure V-4 and V-5).

Previous research (93) has shown that particles 5 microns and larger are retained in the upper respiratory tract. This fraction of the particles is collected on the first two stages of the sampler. Respiratory tract penetration increases with decreasing particle size (93). Particles 1 micron and smaller were retained in the alveoli of the respiratory tract (98), and it is these particles which are the more significant in the causation of respiratory tract infection (99). These smaller particles are found on the two lower stages of the Andersen sampler. An evaluation of the health significance of airborne bacteria, then, should take into account the sizes of the particles on which the bacteria are carried, as well as the total number of bacteria involved.

Thus, if a refuse handling system is designed to remove airborne bacteria, it is especially important to remove the smallest particles which may penetrate the respiratory tract. The smaller particles, however, were found to be more difficult to remove than the larger particles. The least-squares line of Figure V-6 indicates that as the total number of colonies decreases, the proportion of colonies on stage #6 increases.

The result of this phenomenon is that we might reduce the total number of organisms from 100 to 10 and still have the same number of organisms which are impinged on stage #6. Thus, the respiratory tract hazard is not reduced in direct proportion to the reduction of total bacteria.

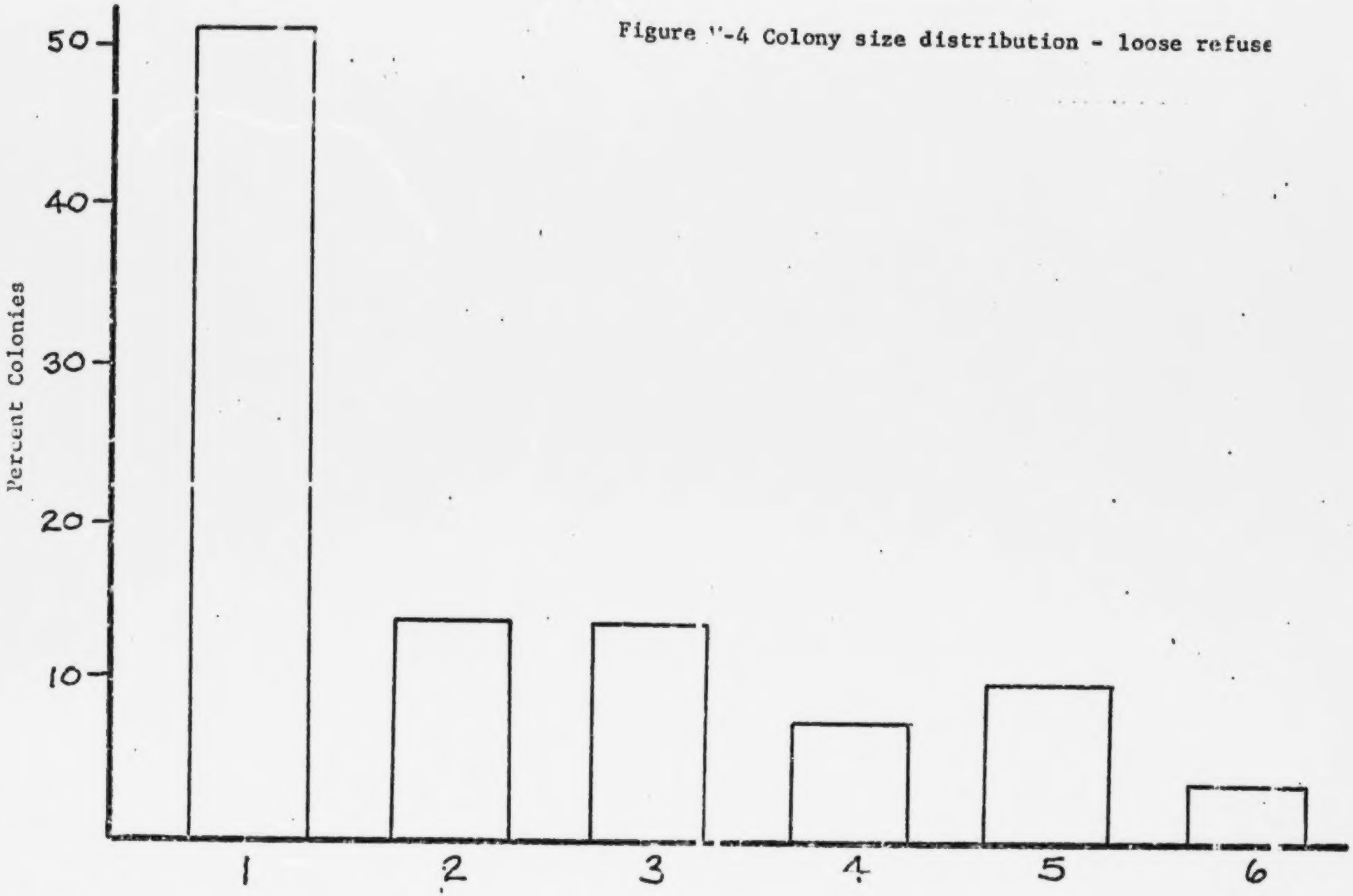


Figure V-4 Colony size distribution - loose refuse

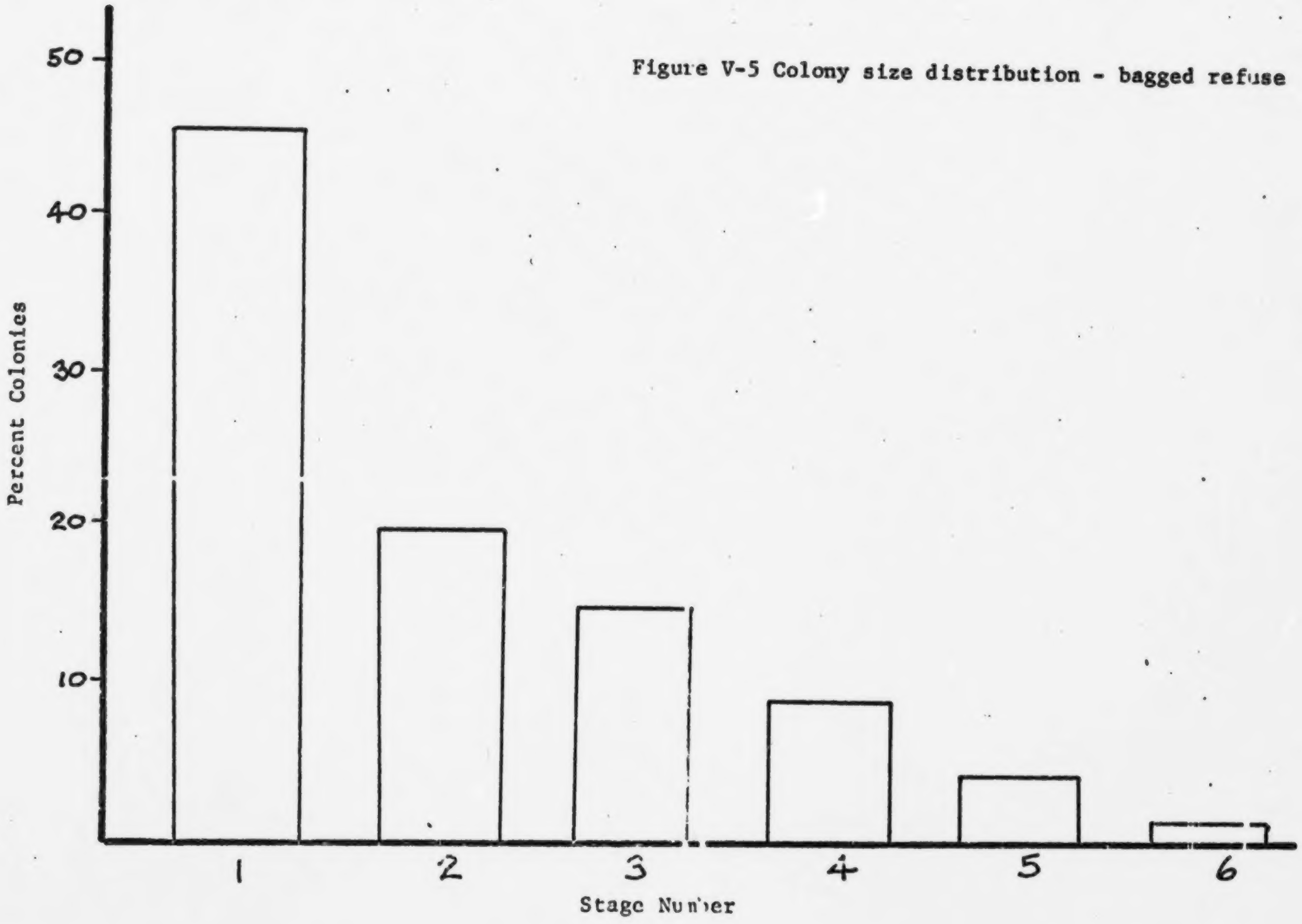


Figure V-5 Colony size distribution - bagged refuse

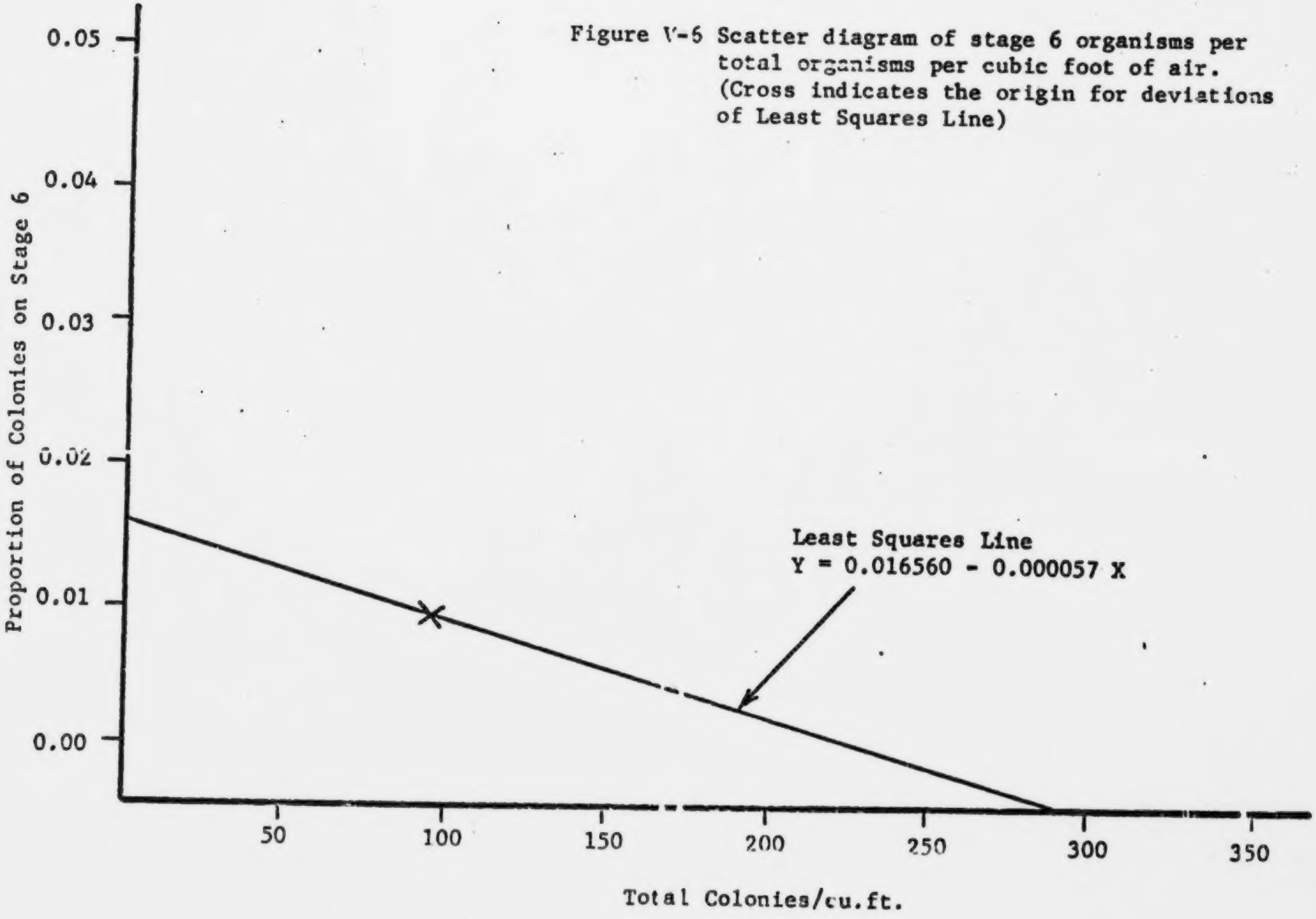


Figure V-6 Scatter diagram of stage 6 organisms per total organisms per cubic foot of air. (Cross indicates the origin for deviations of Least Squares Line)

Table V-8 Distribution of colonies from loose and bagged refuse on Andersen Sampler stages
(per cu. ft.)

Andersen Sampler Stage Number

		1	2	3	4	5	6	Total
Loose Refuse	$\overline{x}$	44.9	21.2	17.9	10.3	3.5	0.8	96.5
	%	45	21	18	11	4	1	100
	Range	5-192	4-73	1-81	3-46	3-12	1-3	17-402
	$s_{\overline{x}}$	36.7	15.6	15.6	8.8	2.6	0.9	78.7

		1	2	3	4	5	6	Total
Bagged Refuse	$\overline{x}$	4.9	1.3	1.3	0.4	0.7	0.6	9.4
	%	52	15	15	4	8	6	100
	Range	1-20	0-3	0-4	0-3	0-2	0-5	3-29
	$s_{\overline{x}}$	3.9	0.8	1.1	0-9	9.0	1.0	5.3

Legend

$\overline{x}$ = Mean

% = Percent of total

$S_{\overline{x}}$ = Standard Deviation

Conclusions

From the preceding analysis of the data we conclude:

1. Airborne bacteria are generated in the handling of this hospital's refuse.
2. Placing the refuse in bags reduces the total number of airborne bacteria generated.
3. The smaller particle sizes which can penetrate the respiratory tract are not removed as easily as the larger particles.

From the velometer studies of airflows we conclude:

1. The possibility exists for viable organisms to be transmitted to other parts of the hospital by way of the refuse chute.
2. The air in the chute tends to flow upward with a tendency to flow out into the hallways. If two or more chute doors are open at the same time, the air flows through the highest open door at a rate several times the flow if only one door was open.
3. The doors do not fit tightly so there is a constant leakage of air into the hallway.
4. There is a hazard presented by the backing up of refuse in the chute, packing refuse against the chute doors. This is especially dangerous because the first chute door above the chute closet is in the kitchen area.

Virological Studies

Introduction

The dissemination of microorganisms by various waste materials has been recognized for many years. To develop controls and preventive measures, a greater knowledge of the basic factors causing the problem is necessary. Significant results have been obtained with bacteria, but little is known about the persistence of viruses on these materials. It is for this reason that the following work was undertaken.

In this work the persistence of coxsackievirus A-9, poliovirus type 1, influenza virus PR-8 and vaccinia virus on various solid waste materials was studied. Samples artifically contaminated with the viruses were held at room temperature until tested. Attempts were made to evaluate the efficiency of recovery, some of the factors which might influence the efficiency, and the duration of infectivity of virus adsorbed to various solid wastes.

Methods and Materials

Viruses

Coxsackievirus A type 9, the PR-8 strain of influenza virus A, the Sabin strain of poliovirus type 1 and vaccinia virus used in this work were laboratory strains passed an undetermined number of times in various tissue culture systems. All stock virus was prepared in GMK bottle cultures by inoculating them with 1.0 ml of undiluted virus. Culture fluids from the bottles showing complete cytopathogenic effect (CPE) or, as with the influenza virus, a high degree of hemadsorption (HAd), on or before the fifth day of inoculation were pooled. The fluids were centrifuged for clarification and dispensed in 10 ml aliquotes in sterile screw-cap vials to be stored at -70 C. Before harvesting the influenza virus, cultures were frozen and thawed two times.

Culture Media

African green monkey kidney (GMK) and HeLa cells (derived from a human cervical carcinoma) were obtained from Flow Laboratories, Rockville, Maryland. All cell cultures were grown in Eagle's minimal essential medium (E-MEM) containing Eagle's salts, glutamine (2 mole/ml), $NaHCO_3$ (1.4 mg/ml) and calf serum. The GMK bottle cultures were grown using 2% calf serum, whereas the roller tubes were grown in a 10% concentration. Both bottle cultures and roller tubes of HeLa cells were grown in 10% calf serum and 10% tryptose phosphate broth (TPB). Maintenance medium for GMK cells was E-MEM supplemented with 0.5% calf serum, whereas the maintenance medium for HeLa cells contained 2% calf serum in E-MEM. All media contained 100 units of penicillin, 100 μg of streptomycin and 25 μg of Fungizone (E. R. Squibb & Sons, New York) per ml.

Cell Cultures

Confluent monolayers of GMK and HeLa cells were grown in 4 oz. prescription bottles with 10 ml of growth medium. Twenty-five roller tube cultures (16 x 125 mm) were prepared per bottle of GMK cells after 5-7 days of growth in bottle culture. HeLa cell roller tubes were also prepared, 25 tubes per bottle culture, after 3 days of growth.

The HeLa cell line was monitored for Mycoplasma at each transfer by plating on Chanock's medium (100). These plates were incubated anaerobically at 37°C for 2-3 weeks before discarding as negative. Cells contaminated with Mycoplasma were not used.

Virus Titrations

All viruses were titered in GMK cells except polio-virus type 1 which was titered in HeLa cells. Hemadsorption was used as an index of infection with influenza virus, whereas CPE was used for all others. Serial tenfold dilutions of the viruses were made in maintenance medium and for each dilution, five roller tuves were inoculated with 0.2 ml of that dilution. The titration endpoints were calculated by the method of Reed and Muench.

Solid Waste Extraction Medium

Except where noted, the following medium, based on that used by Sidwell et al. (87), was used to recover virus from artifically contaminated samples of solid waste.

Eagle's salt solution (10X)	100 ml
MEM amino acids[a] (50X)	20 ml
Sodium hydroxide (1N)	4 ml
Sodium bicarbonate (2.8%)	50 ml
MEM vitamins[a] (100X)	10 ml
Glutamine (100X)	10 ml
Gamma globulin-free calf serum[a]	50 ml
Chick embryo extract[a]	5 ml
Penicillin[b] (100,000 units/ml)	5 ml
Streptomycin[b] (100,000 μg/ml)	5 ml
Amphotericin B[c] (5 mg/ml)	1.0 ml
Double distilled water (q.s.)	1000 ml

Selection and Preparation of Solid Waste Samples

Solid waste was collected from strategic points in the West Virginia University hospitals refuse disposal system. These samples were sorted into arbitrary categories and weighed individually. The criteria used in determining which materials were to be tested were the following: the item should be found in a large proportion of the random samples taken and be present in significant percentages therein; the item should have an object-to-person or interperson frequency which would make them potential threats; and the item should be relatively easy to test. From the above criteria came the following categories:

---

[a] Grand Island Biological Company, Grand Island, N. Y.

[b] Eli Lilly & Company, Indianpolis, Indiana

[c] E. R. Squibb & Sons, N. Y.

A.	Office papers including typing paper, envelopes, carbon paper, newspaper and magazines	50%
B.	Laboratory paper towels, Kleenex and wrapping paper	20%
C.	Cloth including rags, facemasks and elastic items	17%
D.	Surgical tapes, gauze and bandages	8%
E.	Paper and plastic cups	5%

The approximate percentages of each category as it was found in the refuse disposal system is given after its description. A representative sample was then prepared which expressed these percentages. The representative sample and each of the above were pulverized in a Wiley Mill (Arthur H. Thomas Co., Philadelphia, Pa.)

The following items were chosen to be tested in the unpulverized state:

1. Gauze
2. Cotton balls
3. Paper towels
4. Paper cups
5. Cotton cloth

Treatment of Pulverized Materials

Except where noted, all categories of the waste including the representative sample, were tested in the following manner. One-half gram samples of the pulverized materials were placed in culture tubes (25 x 100 mm), autoclaved and allowed to dry for one day. Each sample was then contaminated with 0.4 ml of a known amount of virus and incubated at room temperature. Virus titers were determined for each sample at various intervals of time until no virus could be detected.

Treatment of Unpulverized Materials

Except where noted, the unpulverized materials were cut into 3 x 3 inch pieces, placed in Petri dishes and autoclaved. After drying for one day, they were contaminated with 0.4 ml of a known amount of virus and incubated at room temperature. Virus titers were determined for each sample at various intervals of time until no virus could be detected.

Recovery of Virus from Samples

Throughout this work, 0.4 ml of a known amount of virus has been added to each sample. To recover the virus in each tube, samples were mixed with 15 ml of extraction medium adjusted to pH 7.2. Mixing was carried out on a Super-Mixer (Lab-Line Instruments, Inc., Melrose Park, Illinois) run at speed setting 6 for 15 seconds. After settling for 5 minutes, the fluids were removed and centrifuged at 4°C at 15,000 rpm's for 15 minutes to remove suspended materials. The virus titers of the supernatant fluids were determined by assay in GMK or HeLa cells grown in roller tube cultures.

Those samples not autoclaved before testing were allowed to settle for 30 minutes after mixing and were centrifuged for 30 minutes at 15,000 rpm's to remove bacteria and fungi.

The materials tested in the unpulverized state were macerated with 15 ml of extraction medium in a Sorvall Omnimix homogenizer (Ivan Sorvall, Inc., Norwalk, Conn.) run at full speed for 30 seconds (87). Centrifugation and virus assay were carried out as described for the pulverized samples.

All samples taken in this work were stored at -20°C until tested except the influenza virus samples which were stored at -70°C.

Results and Discussion

Throughout this work, control samples, uncontaminated with virus, were assayed with the experiment. In no instance did control materials damage cell cultures.

Effect on Virus Recovery of Autoclaving and Pulverizing Solid Waste Samples Prior to Contamination

To each of 5 sterile, pulverized and 5 sterile, unpulverized samples was added 0.4 ml of either poliovirus type 1, vaccini virus or coxsackievirus A-9. In addition, 5 unsterile, pulverized and 5 unsterile, unpulverized samples were similarly contaminated. Virus titers were determined after 2 hours at room temperature. In this experiment, 10 ml of extraction medium was used.

Table V-9 shows that neither autoclaving nor pulverizing had an affect on virus recovery. In addition, most of the virus added to all samples was recovered at that time period. Based on these results, waste samples used throughout this work were autoclaved.

Effect of the pH of the Extraction Medium upon the Recovery of Virus from Solid Waste Samples

To pulverized samples of cotton, gauze and paper was added 0.4 ml of either vaccinia virus, poliovirus type 1, coxsackievirus A-9 or influenza virus PR-8. Virus titers were determined after 24 hours using extraction medium adjusted to either pH 2.5, 5.0, 7.0 or 9.0.

In nearly all instances, the efficiency of virus recovery was greater when the pH of the extraction medium was 7.0 (Table V-10). For the remainder of this work, the extraction medium was adjusted to pH 7.2.

Recovery of Virus from Solid Waste Suspended in Distilled Water

A 4 gram aliquot of the representative sample was suspended in 500 ml of distilled water, autoclaved, allowed to cool and dispensed in 15 ml quantities in culture tubes (25 x 100 mm). Each tube was contaminated with 0.4 ml of a known amount of either poliovirus type 1 or coxsackievirus A-9. In addition, some of the suspension was centrifuged at low speed and the resulting supernatant fluid was contaminated with virus. This would detect possible toxic properties of the extract for the viruses or the tissue culture systems in which they were assayed. Tubes were incubated for 2 hours at room temperature or in a 4°C water bath.

In Table V-11, no difference in virus recovery was seen between the contaminated suspension and the contaminated extract. Those tubes held at room temperature showed no significant variation from those kept at 4°C. Thus, the extract had no apparent toxicity for the viruses or the tissue culture systems.

Table V-9 Effect of virus recovery of autoclaving and pulverizing solid waste samples prior to artificial contamination with vaccinia virus, Poliovirus 1 or Coxsackievirus A-9

Virus	Sample[b]	Virus titer[a]			
		Autoclaved		Unautoclaved	
		Pulverized	Unpulverized	Pulverized	Unpulverized
Polio 1 (6.27)[c]	A	6.20	6.16	6.26	6.18
	B	6.27	6.00	6.29	6.17
	C	6.07	6.20	6.20	5.98
	D	5.96	5.87	6.00	6.16
	E	5.87	5.88	6.07	6.27
Vaccinia (5.78)	A	5.75	5.75	5.75	5.70
	B	5.75	5.70	5.60	5.69
	C	5.61	5.70	5.61	5.65
	D	5.75	5.61	5.69	5.69
	E	5.61	5.59	5.60	5.65
Coxsackie A-9 (6.05)	A	6.00	6.05	6.10	6.01
	B	6.05	5.81	5.80	5.98
	C	6.01	5.98	5.91	5.74
	D	6.27	5.81	6.01	5.81
	E	5.80	5.91	5.98	5.90

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] Sample A = mixture of B-E; Sample B = office papers; Sample C = paper towels and tissues; Sample D = paper and plastic cups; Sample E = surgical tape, gauze and bandages.

[c] The titer of virus contained in each sample after the addition of 10 ml of extraction medium. (Log_{10} TCID_{50} per 0.2 ml).

Table V-10 Effect of the pH of the extraction medium upon the recovery of virus from autoclaved, pulverized samples of solid waste artifically contaminated 24 hours previously with vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and influenza virus PR-8

Sample	pH	Virus titer[a]			
		Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
Cotton	2.5	2.37	4.94	4.83	6.00
	5.0	2.64	5.00	5.10	5.96
	7.0	3.00	5.26	5.10	6.00
	9.0	3.00	5.16	4.78	6.00
Gauze	2.5	2.49	4.43	5.15	5.48
	5.0	2.67	4.17	4.83	6.00
	7.0	3.37	5.30	5.00	6.00
	9.0	3.16	4.50	5.15	5.95
Paper	2.5	1.00	4.50	5.00	5.84
	5.0	2.17	4.30	4.16	6.00
	7.0	3.00	4.83	5.18	6.00
	9.0	2.67	4.62	4.80	6.16

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium. (Log_{10} TCID_{50} per 0.2 ml).

Table V-11 Recovery of Poliovirus 1 and Coxsackievirus A-9 from artifically contaminated solid waste suspended in distilled water

Treatment	Experiment number	Virus titer[a]			
		Supernatant fluid from contaminated suspension[b]		Supernatant fluid extracted before contamination[c]	
		Polio 1 (5.33)[d]	Coxsackie A-9 (5.18)	Polio 1 (5.33)	Coxsackie A-9 (5.18)
Tubes incubated 2 hrs 4°C.	1	5.03	5.10	5.20	5.10
	2	5.16	5.05	5.00	5.15
	3	5.30	5.00	4.93	5.20
	4	5.20	5.11	5.10	5.00
	Mean	5.17	5.06	5.06	5.12
Tubes incubated 2 hrs Room Temp.	5	5.20	5.93	5.00	5.00
	6	5.12	5.00	5.30	5.15
	7	5.00	5.10	4.90	5.10
	8	5.25	5.16	5.00	5.11
	Mean	5.14	5.04	5.05	5.09

[a] $\log_{10}$ $TCID_{50}$ per 0.2 ml.

[b] The contaminated suspension was centrifuged and the supernatant fluid tested for virus.

[c] The sterile suspension was centrifuged and the supernatant fluid was contaminated and tested for virus.

[d] The titer of virus contained in each sample after dilution to final volume.

Persistence Studies

The next five experiments were carried out on unpulverized materials by contaminating them with 0.4 ml of either vaccinia virus, poliovirus type 1, coxsackievirus A-9 or influenza virus PR-8. Virus titers were determined at zero time, 1, 2, 3, and 5 days and thereafter once a day until no virus could be detected.

Persistence of Virus on Cotton Balls

Influenza virus PR-8 persisted on this material until the eighth day after contamination. Vaccinia virus and poliovirus type 1 were undetectable at 7 days, while coxsackievirus A-9 survived 3 days (Table V-12). No general trend of virus inactivation could be seen. Virus loss for one day ranged from 0.2 to 2.0 log units in most cases. The fastest loss was recorded for the period 1-3 days during which time coxsackievirus A-9 lost 4 log units.

Persistence of Virus on Paper Towels

The results (Table V-13) show that vaccinia virus and poliovirus type 1 were again undetectable after 7 days. Coxsackievirus A-9 persisted for 3 days, while influenza virus PR-8 survived until the seventh day. Coxsackievirus A-9 again lost 4 log units in 2 days as compared to 0.2 to 2.0 logs for the other viruses.

Persistence of Virus on Cotton Cloth

Table V-14 shows that on this material, poliovirus type 1 and coxsackievirus A-9 persisted for 3 days, while vaccinia virus and influenza virus PR-8 survived until the fifth day. No pattern of inactivation could be seen for any of the viruses, although each lost between 3-4 log units in 2 days.

Table V-12 Persistence of vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on cotton balls at room temperature

Incubation time (days)	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
0	4.40	5.25	5.00	5.83
1	3.48	5.00	4.83	5.00
2	2.50	4.26	2.62	4.50
3	1.62	3.16	0.50	3.25
5	0.75	1.71	0.00[c]	2.16
7	0.00	0.00	0.00	0.50

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium. (Log_{10} TCID_{50} per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Table V-13 Persistence of vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on paper towels at room temperature

Incubation time (days)	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
0	4.36	5.00	5.00	6.00
1	3.83	4.37	4.83	5.50
2	2.62	3.50	2.33	4.56
3	1.62	2.00	0.83	4.00
5	0.75	0.50	0.00[c]	2.05
7	0.00	0.00	0.00	0.00

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium. (Log_{10} TCID_{50} per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Table V-14 Persistence of vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on cotton cloth at room temperature

Incubation time (days)	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
0	4.41	5.28	4.83	5.75
1	2.68	4.37	1.83	4.56
2	1.83	3.30	1.00	3.00
3	1.30	1.80	0.83	1.96
5	0.83	0.00[c]	0.00	0.75
7	0.00	0.00	0.00	0.00

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium. (Log_{10} TCID_{50} per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Persistence of Virus on Surgical Gauze

Vaccinia virus could not be detected after 3 days, while poliovirus type 1, coxsackievirus A-9 and influenza virus PR-8 were recovered on the fifth day (Table V-15). A loss of 1 log unit was recorded for vaccinia virus at zero time and was considerably higher than that observed for the other viruses.

Persistence of Virus on Wax Coated Paper Cups

Table V-16 shows that all viruses persisted until the fifth day after contamination. Influenza virus PR-8 lost 5 log units from zero time to 3 days, while the others lost between 3 and 4 log units. No pattern of loss could be seen with any of the viruses.

Studies on Pulverized Materials

One-half gram samples of the waste were contaminated with 0.4 ml of either vaccinia virus, poliovirus type 1, coxsackievirus A-9 or influenza virus PR-8. Virus titers were determined at zero time, 2, 6, and 9 hours and thereafter once a day until no virus could be detected.

Persistence of Virus on the Pulverized Representative Sample

Vaccinia virus persisted until the fifth day, whereas poliovirus type 1 and influenza virus PR-8 survived until the seventh day (Table V-17). Coxsackievirus A-9 was undetectable after 6 days. Almost no virus was lost in the first 9 hours after contamination. Thereafter, losses ranged from 0.1 to 1.5 log units per day for each virus.

Persistence of Virus on Pulverized Office Papers

Table V-18 shows that poliovirus type 1 persisted up to the sixth day, while the other viruses lasted until the seventh day. No pattern of inactivation could be seen for any of the viruses. Losses ranged from 0.1 to 1.5 log units per day for each virus.

Table V-15 Persistence of vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on surgical gauze at room temperature

Incubation time (days)	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
0	3.90	5.30	5.10	6.00
1	2.37	5.16	5.00	5.50
2	1.16	4.30	2.62	3.28
3	0.50	1.50	1.62	1.79
5	0.00[c]	0.50	0.75	0.62
7	0.00	0.00	0.00	0.00

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium. (Log_{10} TCID_{50} per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Table V-16 Persistence of Vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on wax coated paper cups at room temperature

Incubation time (days)	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
0	4.80	5.21	5.06	5.95
1	3.25	4.98	4.16	4.65
2	2.62	3.21	2.83	3.00
3	1.83	2.50	1.62	1.00
5	0.50	0.50	0.75	0.60
7	0.00[c]	0.00	0.00	0.00

[a] Log_{10} $TCID_{50}$ per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium. (Log_{10} $TCID_{50}$ per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Table V-17 Persistence of Vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on an autoclaved, pulverized solid waste mixture at room temperature

Incubation time	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18	Influenza PR-8 (6.07)
(hours)				
0	4.21	5.31	5.00	5.97
2	4.00	4.83	4.90	5.90
6	4.00	4.78	4.85	5.41
9	3.85	4.73	4.00	5.35
(days)				
1	3.00	4.62	3.41	4.83
2	2.62	3.62	2.83	4.21
3	2.00	2.83	2.00	3.52
4	1.75	2.50	1.62	2.82
5	0.50	2.37	1.00	2.17
6	0.00[c]	2.17	0.81	1.62
7	0.00	1.35	0.00	0.83
8	0.00	0.00	0.00	0.00

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium (Log_{10} TCID_{50} per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Table V-18 Persistence of Vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on an autoclaved, pulverized sample of office papers at room temperature

Incubation time	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
(hours)				
0	4.50	5.16	4.98	6.00
2	4.25	4.62	4.98	5.51
6	4.12	4.59	4.58	5.21
9	4.00	4.58	4.40	5.00
(days)				
1	3.62	4.20	4.12	4.27
2	3.34	2.83	3.93	3.33
3	3.12	2.62	3.21	3.05
4	2.54	2.17	2.81	2.50
5	1.89	1.45	2.12	2.17
6	1.75	0.75	1.62	1.21
7	0.62	0.00[c]	0.50	0.50
8	0.00	0.00	0.00	0.00

[a] $\log_{10}$ $TCID_{50}$ per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium ($\log_{10}$ $TCID_{50}$ per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Persistence of Virus on Pulverized Paper Towels, Tissues and Bags

Influenza virus PR-8 was detected until the seventh day, while poliovirus type 1 was detected until the eighth day (Table V-19). Vaccinia virus was also recovered until the seventh day. No significant losses were recorded in the first 9 hours after contamination. Losses per day were approximately 0.5 to 1.0 log unit for each virus.

Persistence of Virus on Pulverized Paper and Plastic Cups

The initial zero time isolation with vaccinia virus showed a loss of 0.8 log units (Table V-20). Vaccinia virus persisted for 6 days on the material, coxsackievirus A-9 and poliovirus type 1 survived until the seventh. Influenza virus PR-8 lasted the longest by persisting until the eighth day.

Persistence of Virus on Pulverized Surgical Tape, Gauze and Bandages

Influenza virus PR-8 persisted for 5 days, while poliovirus type 1 lasted 6 days (Table V-21). Vaccinia virus and coxsackievirus A-9 also persisted for 5 days. The greatest loss of the three was recorded for coxsackievirus A-9 when it lost 4 log units in 3 days.

Effect on Virus Recovery of Pulverizing Paper Towels After Contamination with Virus. Transmission of Virus from Contaminated to Uncontaminated Paper Towels by Direct Contact

Paper towel samples (5 x 5 inches) were contaminated with 0.4 ml of a known amount of either vaccinia virus or coxsackievirus A-9. Each sample was placed in a plastic bag containing three additional uncontaminated towels. After three hours at room temperature, the towels were individually pulverized and tested for virus survival.

Virus was recovered from one of the towels contaminated indirectly (Table V-22). No virus was recovered from towels in contact with coxsackievirus A-9. From the towel contaminated with vaccinia virus, 1.0 log unit was recovered, whereas 2.5 log units of coxsackievirus A-9 were recovered.

Table V-19 Persistence of Vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on an autoclaved, pulverized sample of paper towels, tissues and bags at room temperature

Incubation time	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
(hours)				
0	4.62	5.26	5.00	5.84
2	4.50	5.16	5.00	5.75
6	4.00	5.00	5.00	5.21
9	3.81	4.86	4.83	5.00
(days)				
1	3.75	4.83	4.21	4.50
2	2.75	3.83	3.83	4.00
3	2.12	3.53	2.62	3.16
4	1.86	2.37	2.17	2.41
5	1.12	2.17	1.85	2.00
6	0.62	1.75	1.00	1.15
7	0.00[c]	0.50	0.50	0.00
8	0.00	0.00	0.00	0.00

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium (Log_{10} TCID_{50} per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Table V-20 Persistence of Vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on an autoclaved, pulverized sample of paper and plastic cups at room temperature

Incubation time	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
(hours)				
0	4.12	5.30	5.10	5.89
2	4.00	5.27	5.00	5.89
6	4.00	5.27	5.00	5.61
9	3.86	5.15	5.00	5.50
(days)				
1	3.62	5.00	4.62	5.21
2	3.26	4.75	4.16	5.16
3	2.83	3.62	3.55	5.00
4	2.12	2.62	2.62	4.35
5	1.75	1.50	1.59	3.21
6	0.50	0.65	1.07	1.62
7	0.00[c]	0.50	0.83	1.00
8	0.00	0.00	0.00	0.50

[a] Log_{10} $TCID_{50}$ per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium (Log_{10} $TCID_{50}$ per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Table V-21 Persistence of Vaccinia virus, Poliovirus 1, Coxsackievirus A-9 and Influenza virus PR-8 on an autoclaved, pulverized sample of surgical tapes, gauze and bandages at room temperature

Incubation time	Virus titer[a]			
	Vaccinia (4.91)[b]	Polio 1 (5.33)	Coxsackie A-9 (5.18)	Influenza PR-8 (6.07)
(hours)				
0	4.86	5.26	4.83	5.83
2	4.75	5.16	4.75	5.50
6	4.62	5.00	4.62	5.21
9	4.62	5.00	3.83	5.00
(days)				
1	4.00	4.83	2.83	4.75
2	3.75	3.83	1.54	4.00
3	2.83	2.50	1.00	3.21
4	1.12	2.00	0.83	2.16
5	0.83	1.62	0.50	1.00
6	0.00[c]	0.83	0.00	0.00
7	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium (Log_{10} TCID_{50} per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Table V-22 Effect on virus recovery of pulverizing paper towels after artificial contamination with Vaccinia virus and Coxsackievirus A-9. Transmission of virus from contaminated to uncontaminated paper towels by direct contact

Sample towels	Virus titer[a]	
	Vaccinia virus (4.28)[b]	Coxsackievirus A-9 (4.83)
Contaminated	1.00	2.50
Uncontaminated		
1	0.00[c]	0.00
2	0.83	0.00
3	0.00	0.00

[a] Log_{10} TCID_{50} per 0.2 ml.

[b] The titer of virus contained in each sample after the addition of 15 ml of extraction medium (Log_{10} TCID_{50} per 0.2 ml).

[c] No virus detectable in 0.2 ml of undiluted fluid.

Conclusions

Before undertaking control and preventive measures for stopping the spread of microorganisms by fomites, an understanding of the factors influencing the contamination of the materials and the factors influencing the survival and infectivity of the microorganisms on the materials is needed. This work has supplied additional information on virus stability to the limited amount available today.

Maximum recovery of virus was obtained when the medium used for extraction was adjusted to pH 7.0. In addition to maximum recovery at this pH, none of the harmful effects for the virus that were exhibited at the lower pH levels were observed.

It was thought that the pulverizing or autoclaving might be exerting an influence on the recovery of virus. However, virus was recovered from treated materials with little difference in efficiency from those that were not autoclaved or pulverized. To facilitate testing, most samples were autoclaved before being used.

To find if these materials had any properties toxic for viruses or for tissue cultures, an extract of a representative mixture of solid wastes was tested. No toxic substances could be shown in the materials that were used. But in much of the solid waste generated in a hospital exists toxic chemicals and disinfectants which could be virucidal in nature. Viruses are apparently susceptible to inactivation by a number of chemical substances. (Reviewed by Dunham (101) and by Klein and DeForest (102). In this study, the materials were tested as they were found in the refuse disposal system where they posed the greatest threat to the greatest number of people. If present, the chemical agents had no adverse effect on the tissue cultures used. This could be due to the autoclaving which would change the compound significantly or to their removal by the clarification centrifugation.

The use of chemical agents for the sanitizing of fabrics from bacteria has been extensively used since the days of the Roman Empire, but to date no attempts have been made to use this process to render fabrics refractory to viruses. If effective chemicals can be found that have significant activity against a broad spectrum of viruses, fabrics could be treated with the agent, particularly in areas suspected of being contaminated with the susceptible viruses.

Persistence of viruses on the materials tested seemed to vary with the virus used and the type of waste. Since no pattern of loss of virus on cotton materials or paper items could be seen, it was assumed that the factors influencing the survival on the various materials were peculiar to the individual item or group of items being tested. In this study, cotton cloth was the only fabric studied, but sufficient information already exists to indicate that other types of fabrics can disseminate viruses.

Differences in the fibrous structure of waste materials may have some effect on their retention of virus. Cotton fibers are flattened, twisted cellulose tubes with a small amount of pectins and waxes in the outer wall, whereas the paper products consist of polyester and cellulose in various concentrations depending on the item being studied. The paper fibers are laid down either randomly, parallel or at right angles. In laboratory paper towels there is more polyester than cellulose. The natural water content of cotton materials is about 7%, whereas for paper items it is less. Approximately 20-41% of the cotton material is unoccupied space, whereas paper has less space. The possibility exists that viruses might be held more tightly on one type of fiber than on another depending upon which offers the most protection, thus allowing recovery of virus to be higher from one material than from another. Virus clumping could also prevent their release from the fibers. However, since the virus titer decreased in most cases at a steady rate with increasing time, the implication is that the agent lost its viability upon incubation. Relative humidity (RH) has been shown to be an important factor in the survival of viruses (103,104,105, 106,107,108). Due to evaporation after addition of the virus suspension, the moisture content slowly decreased. At least at one point in the drying process, the humidity within the samples reached levels that should have favored survival of the virus. Perhaps on a material that held its moisture less readily, as with cotton cloth in Table V-14, the enteric viruses lost their viability sooner than the vaccinia and influenza viruses. These results would be in accordance with the findings of other investigators (87,103,105,109). However, this could not account for other results which are believed to be caused by individual variation.

Viruses persisted on the pulverized materials slightly longer than on those that were unpulverized. In Table V-19, all viruses persisted on pulverized paper towels for 6-7 days, whereas on regular paper towels, they lasted for 3-5 days (Table V-13). This again could be due to the rate of water loss and/or the fiber construction after pulverization, but these results are hard to interpret.

To determine the effect of pulverizing after contamination, samples of paper towels were tested. Another question was answered by this experiment; do viruses contaminating one object contaminate another one by coming in contact with it? Virus was recovered from only one towel that was originally uncontaminated. This shows that contamination of viruses can be spread from one object to another merely by mixing the two. Most of the virus that was originally placed on the towels was lost during the pulverizing process, which could probably be attributed to the heat generated in the pulverizing mill.

The results presented in this work support the thesis that almost all solid waste materials found in the refuse disposal system at West Virginia University hospital could be possible vehicles of transmission of viruses. To insure public safety from exposure to possible contamination by infectious agents harbored on these materials, refuse containers should be designed which allow the least contact between person and waste. Plastic bags have met with relative success, but in many cases were easily torn open by sharp objects with which they came into contact. These containers would be employed in all areas of the hospital since all areas generate materials capable of retaining infectious microorganisms. At regular collection times, the containers would be sealed and carted away to be disposed of in a way that is effective yet minimizes possible pollution of air and water. Possibly, high risk areas could be decided upon so that special precautions could be taken in handling the waste generated there.

VI. SAFETY PRECAUTIONS, COSTS AND RECOMMENDED SAMPLING PROCEDURE

As the title of this chapter indicates this is a compilation of some studies which evolved as a result of the overall study.

Safety Precautions

Concern here is for certain steps which were considered necessary for the personnel who were working on the project and some additional recommendations for the personnel whose job it is to handle the wastes in the institution.

Most of the concern for personnel working on the project pertained to work in the laboratory. They were required to wear laboratory coats, surgical face masks and rubber gloves while sorting, weighing and grinding. In addition, goggles were required during the grinding operation. They were urged to shower after working. The laboratory coats were commercially laundered and the laboraboty was cleaned after each days sorting.

New brown paper was placed on the sorting table at the beginning of each days work or as often as needed to maintain clean conditions.

Bags of refuse known to contain pathogenic organisms were weighed only and not sorted.

The following recommendations although partially applicable to personnel working on this project apply mainly to waste handlers in the institution.

1. Disposable needles and syringes are a hazard to waste handlers. Some system to crush, melt, break or otherwise incapacitate these devices should be a part of each health care facility that uses them.
2. Unused portions of certain medicines, narcotics or other drugs used in health care facilities should be poured down the drain, crushed or otherwise made unusable prior to disposal.
3. A comprehensive investigation of sickness or disease rates of refuse handlers in hospitals should be conducted.

4. Radioactive wastes should be handled and disposed of according to methods prescribed by the U. S. Atomic Energy Commission.
5. Separate storage and disposal should be required for flammable or dangerous chemicals, liquids and toxic compounds.

Solid Wastes Handling Costs

Although this was not a specific aim in this study of the handling of solid wastes at the Center it arose and was carried out.

The following factors were considered in estimating costs of the Basic Sciences Building and the Teaching Hospital:

1. Personnel
2. Salaries of personnel
3. Time spent by personnel in the handling of solid wastes
4. Equipment and supplies
5. Maintenance and replacement of equipment
6. Utilities
7. Other related factors

Personnel included custodians, maids, kitchen help and special service help.

Other related factors include periodic cleaning of air filters, removal of fly ash and so forth.

Exact costs on many items were difficult to determine and hence some of the figures shown below represent our best estimate of cost.

Basic Sciences Building - Annual Costs

1.	Physical Plant - Medical Center Department Personnel - Custodians, maids, etc.	$ 28,030
2.	Physical Plant - University Personnel - Truck driver, etc.	3,035
3.	Purchasing and Supply Department	980
4.	Kitchen Cafeteria and Snack Shop	725
5.	Animal Quarters - Including Incineration	2,594
6.	Human Waste Incineration	1,220
7.	General Refuse Incineration	430
8.	Radioactive Waste	216
	Total Annual Cost	$ 37,230

Teaching Hospital - Annual Costs

1. Housekeeping Personnel	$ 28,483
2. Physical Plant - University Personnel	4,430
3. Physical Plant - Medical Center Department Personnel	115
4. Kitchen, Cafeteria, and Coffee Shop	5,594
5. General Refuse Incineration	1,075
6. Chute Maintenance	60
7. Laundry Wastes	293
Total Annual Cost	$ 40,050

General refuse incineration costs are prorated between the Basic Sciences Building and the Teaching Hospital and include depreciation.

The total cost of refuse handling and disposal thus comes to $77,280 per year and using a rough approximation of 1,000 tons of refuse generated per year this gives a cost of handling and disposal of $77.28 per ton.

Recommended Sampling Procedures

A number of factors arose during the course of this study pertaining to sampling procedures such that it is felt that some general recommendations can be made which should assist other investigators in further studies.

1. A sufficient number of stations should be selected so that wastes from a particular unit may be isolated and identified as being from that particular unit.
2. Samples must be collected enough times from any sampling station so that the effect of diurnal or seasonal variation can be detected if it is present.
3. Periodic checks of weights from individual sampling stations should be compared to total production from the facility to verify the validity of station sampling.
4. Twenty-four hour attendance at sampling stations may be necessary.
5. If wastes are handled in such a way that certain hours are peak hours at a disposal point additional study personnel may be required during that period.

6. The amount of waste which can be sorted, ground and analyzed is usually a limiting factor and is another justification for having a series of stations in the facility being studied.
7. If the sample sorted is relatively large 50 to 100 pounds of a representative portion must be selected for chemical and bacteriological analysis. The procedure used in this study was to take a 5 to 10 percent sample by weight of each item from the physical separation and grind these together for the chemical analysis.

Some idea of the time required for sorting, sampling and grinding may be seen in Table VI-1.

Table VI-1 Labor efficiencies for refuse sorting, sampling and grinding

	Hospital	Basic Sciences	Total
Pounds of refuse sorted, sampled and ground	3528	3704	7232
Pounds of refuse sorted only	668	8405	9073
Labor hours spent in sorting sampling and grinding	324	351	675
Labor hours spent in sorting only	52	752	804
Pounds per labor hour for sorting, sampling and grinding	10.89	10.54	10.69
Pounds per labor hour for sorting only	12.86	11.16	11.02

VII. SUMMARY

The specific aims which were initially listed for this project are given below.

1. To determine the physical and chemical composition of the solid wastes from one medical school and hospital referral complex.
2. To determine whether bacteria and viruses are present to any significant degree and to do some isolation and identification.
3. To provide a classification basis and obtain quantity values for the waste from the significant floors and departments.
4. To establish a safe procedure for studies on potential pathogenic wastes.
5. To provide information about solid wastes on a waste producing unit basis that can be used by designers in establishing waste handling procedures and facilities for hospitals and other medical complexes.
6. To develop a sampling procedure which could be used in future solid waste studies including statistical analysis of the data to determine the percent errors and confidence in the sampling procedure.

It is the primary purpose of this chapter to point out where in the main body of the report the information can be found which will satisfy or partially satisfy the initial specific aims.

Number one can be found in Chapter IV

Number two can be found in Chapter V

Number three can be found in Chapter III

Number four can be found in Chapter VI

Number five can be found in Chapter III

Number six can be found in Chapters II and VI

It was considered more convenient to list the conclusions with the chapters that dealt with that particular topic.

Cost, which were not included as part of the specific aims are discussed in Chapter VI.

Although all pertinent references are listed in the Bibliography a list is also provided here of all papers which were written pertaining to this study. If more detail is desired on any topic discussed in this report these papers are on file with Solid Waste Research, Office of Research and Monitoring, Environmental Protection Agency, Cincinnati, Ohio and with the Department of Civil Engineering, West Virginia University, Engineering Sciences Building, Morgantown, West Virginia 26506.

1. Armstrong, David Harold, "Hospital Refuse - Chute Sanitation," Unpublished problem report, W.V.U., Morgantown, W. Va. 1969.

   This report deals with the general problem of hospital refuse chute sanitation and the specific problem of the effect of putting hospital refuse in plastic bags. The study shows that airborne bacteria are generated during waste handling and that there are pathways by which they may gain entrance to hospital floors. Plastic bagging of the refuse significantly reduced the number of airborne bacteria generated.

2. Cleveland, Elmer G., "Sampling Data and Procedures Used in the Medical Center Solid Waste Program," Unpublished class report, W.V.U., Morgantown, W. Va. 1968.

   This report deals with the design of the sampling and weighing procedure in order to obtain weights, volumes, types and generation origins of solid wastes within the Medical Center complex. Collection of samples, laboratory procedures and safety precaustions are discussed. Preliminary data as to physical breakdown and quantities are presented.

3. DiNicola, Thomas A., "Persistence of Viruses on Hospital Solid Wastes," Unpublished masters thesis, W.V.U., Morgantown, W. Va. 1969.

   This thesis reported on contaminating hospital solid wastes with vaccinia virus, poliovirus type 1, coxsackie virus A-9 and influenza virus PR-8. The length of time these agents persisted at room temperature on such materials was determined. Generally, viruses persisted for 3 to 6 days on cotton balls and sheeting and for 3 to 8 days on paper items.

4. Galli, Alfred A., "Chemical Analysis of Solid Wastes from a Teaching Hospital," Unpublished problem report, W.V.U., Morgantown, W. Va. 1971.

   This problem report is a study of the chemical constituents frund in solid wastes. After a physical separation into 25 categories a chemical analysis which included moisture, volatile solids and ash, BTU value, sulfur and phosphorus was performed. Data obtained during one year of sampling was processed in a computer which provided readouts. Other chemical tests were added after the completion of this report.

5. Morris, Ronald Lee, "Preparation and Operation of Combustion Trains for Carbon and Hydrogen Analysis," Unpublished problem report, W.V.U., Morgantown, W. Va. 1969.

   This report focuses on the construction and method of operation of combustion trains for the analysis of carbon and hydrogen in the chemical analysis of solid wastes at the Medical Center Complex.

6. Proden, Leonard, "Tentative Methods and Procedures for Chemical and Bacteriological Analysis of Institutional Solid Wastes," Unpublished report, W.V.U., Morgantown, W. Va. 1968.

   This report lists suggested procedures to be followed in chemical and bacteriological analysis of hospital solid wastes. It also discusses some safety and sanitary precaustions to be followed as well as suggestions on ways of enhancing the quality of the work being performed.

7. Smith, Richard J., III, "Bacteriological Examination of Institutional Solid Wastes," Unpublished problem report, W.V.U., Morgantown, W. Va. 1970.

   This report deals with the method of examination to be used in the analysis of wastes containing pathogenic microorganisms. Some preliminary data are presented.

8. Trigg, Jere A., "Microbial Examination of Hospital Solid Wastes," Unpublished problem report, W.V.U., Morgantown, W. Va. 1971.

Building on reference number six this report gives a detailed explanation of analysis materials and procedures for the determination of the microbial counts in hospital refuse. Insight is obtained into the question of the types of microorganisms most commonly associated with hospital refuse. From the data on the 15 nursing stations conclusions are drawn on the type of station most likely to generate potentially pathogenic solid wastes.

9. Usmiani, John 1., Part I., "Estimate of Cost Factors Involved in Solid Waste Handling and Disposal at West Virginia University Medical Center", Part 2, "Personnel Involved in Solid Waste Production at West Virginia University Medical Center," Unpublixhed class report, W.V.U., Morgantown, W. Va. 1968.

This report attempts to take into account all factors which contribute to the cost of handling and disposing of solid wastes at the W.V.U. Medical Complex. Part 2 is an effort to correlate these costs with the personnel who are contributing to the production of the solid wastes in the Complex.

10. Wallace, Lynn Pyper, "Solid Waste Generation by the Units of a Teaching Hospital," Ph.D. Dissertation, W.V.U., Morgantown, W. Va. 1970.

After the determination the weights and volumes of solid waste generated by a modern teaching hospital these quantities were correlated the number of patients, the number of paid employees (nurses, doctors, aides, administrative and operational personnel) and the number of non-paid personnel (volunteers and students) who produced the refuse. The results show that the quantity of refuse generated by hospital units can be predicted from the 24 hour staff on duty in that unit.

11. Zepeda, Francisco, "Statistical Analysis of Institutional Solid Wastes," Unpublished problem report, W.V.U., Morgantown, W. Va. 1969.

This report is a study of the percentages of the different physical constituents of institutional solid wastes. The analysis consisted in the physical separation of the refuse into 25 categories and in obtaining the percentage by weight of each.

Data obtained during one year of sampling were processed in a computer and the results obtained showed the quantity of solid waste generated in each section and the percentage by weight of each constituent.

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6. "Disposable Syringes and Needles," Hospitals, Vol. 191, No. 1, January 1965, p. 47.
7. Healy, J. J., "Disposable Hypodermic Syringes and Needles," Journal of the American Medical Association, Vol. 191, January 4, 1965, p. 57.
8. Horty, J. F., "Courts Rule on Unlicensed Doctors, Hazardous Wastes and Claims Priorities," Modern Hospital, Vol. 112, April 1969, p. 56.
9. Deschambeau, G. L., "No More Stray Shots for Disposable Needles and Syringes," Modern Hospital, Vol. 109, September 1967, p. 80.
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APPENDIX A

Appendix A consists of data tables and calculation tables used in obtaining values for certain tables in the main body of the report.

Table A-1 Mean hospital unit population

(24 HOUR PERIOD) MONDAY —— FRIDAY

UNIT	PATIENTS	DOCTORS ADMINISTRATORS SUPERVISORS	SECRETARIES CLERKS	TECHNICIANS LAB ASS'T	NURSES AIDS ORDERLIES	HOUSEKEEPING MAINTENANCE	TOTAL STAFF	VOLUNTEERS STUDENTS
META.	10	7	0	2	8	2	19	3
PSYC.	24	11	1	1	13	2	28	9
GMED.	43	21	2	2	24	4	53	2
GMED.	47	33	2	2	26	4	67	2
PED.	41	41	2	3	24	5	75	12
GYN.	44	36	2	1	20	4	63	3
SURG.	46	18	2	3	25	4	52	1
SURG.	46	24	2	2	25	4	57	2
OB.	15	17	1	0	17	2	37	9
ORTH.	21	8	2	0	16	2	28	3
ORTH.	38	11	2	0	23	4	40	4
OR.	19	34	1	4	36	4	79	0
IC.	8	22	0	0	18	3	43	1
X-RAY	0	10	11	13	0	1	35	22
BLAB.	0	7	9	26	3	1	46	16
REGM.	0	6	5	1	0	0	12	0*
ENT.	0	13	2	5	0	0	20	2*
CP.	0	12	6	9	1	1	29	5
EMG.	0	2	0	2	0	0	4	0
ER.	65	16	1	0	9	3	29	1
CLIN.	311	85	4	9	14	1	113	19
ADMIN.	0	21	41	0	0	4	66	20
CAFE.	0	1	0	5	0	0	6	0
GIFT	0	1	1	0	0	0	2	6
GRND.	0	3	12	8	0	2.	25	0
DIET.	0	4	4	17	0	2	27	0

Table A-1 (continued)

UNIT	PATIENTS	DOCTORS ADMINISTRATORS SUPERVISORS	SECRETARIES CLERKS	TECHNICIANS LAB ASS'T	NURSES AIDS ORDERLIES	HOUSEKEEPING MAINTENANCE	TOTAL STAFF	VOLUNTEERS STUDENTS
KITN.	0	7	0	64	0	2	73	0
PHCY.	0	2	0	6	0	0	8	0
LAUN.	0	2	0	20	0	3	25	0
CENT.	0	1	1	7	0	0	9	0
COBT.	0	1	1	4	0	1	7	0
ALF.	0	6	7	7	3	1	24	0*
TOTALS	778	483	124	223	305	66	1201	142

Includes 376 Outpatients

*Administratively Part Of The Basic Sciences Building

Table A-2 Mean hospital unit population

(24HOUR PERIOD) UNIT	PATIENTS	DOCTORS ADMINISTRATORS SUPERVISORS	SECRETARIES CLERKS	TECHNICIANS LAB ASS'T	NURSES AIDS ORDERLIES	HOUSEKEEPING MAINTENANCE	SATURDAY AND SUNDAY TOTAL STAFF	SATURDAY AND SUNDAY VOLUNTEERS STUDENTS
META.	7	8	0	1	6	2	17	0
PSYC.	18	4	1	1	9	2	17	2
GMED.	41	17	1	1	25	3	47	0
GMED.	45	20	1	1	23	2	47	0
PED.	42	36	1	3	24	5	69	2
GYN.	45	24	1	3	18	4	50	0
SURG.	45	11	1	2	22	4	40	1
SURG.	43	17	1	2	25	3	48	0
OB.	28	6	0	0	18	2	26	0
ORTH.	20	5	1	0	14	1	21	0
ORTH.	32	10	1	0	21	2	34	0
OR.	3	7	0	1	4	1	13	0
IC.	10	19	0	0	14	1	34	0
X-RAY	0	1	1	3	0	0	5	0
BLAB.	0	3	2	13	1	0	19	0
REGM.	0	0	0	0	0	0	0	0
ENT.	0	0	0	0	0	0	0	0
CP.	0	0	0	0	0	0	0	0
EMG.	0	0	0	0	0	0	0	0
ER.	65	4	0	0	8	3	15	2
CLIN.	0	0	0	0	0	0	0	0
ADMN.	0	3	8	0	0	2	13	22
CAFE.	0	1	0	6	0	0	7	0
GIFT.	0	1	0	0	0	0	1	5
GRND.	0	0	0	0	0	0	0	0
DIET.	0	2	3	12	0	1	18	0
KITN.	0	6	0	60	0	1	67	0

Table A-2 (continued)

UNIT	PATIENTS	DOCTORS ADMINISTRATORS SUPERVISORS	SECRETARIES CLERKS	TECHNICIANS LAB ASS'T	NURSES AIDS ORDERLIES	HOUSEKEEPING MAINTENANCE	TOTAL STAFF	VOLUNTEERS STUDENTS
PHCY.	0	1	0	3	0	0	4	0
LAUN.	0	1	0	6	0	1	8	0
CENT.	0	1	0	4	0	0	5	0
COBT.	0	0	0	0	0	0	0	0
ALF.	0	0	0	0	0	0	0	0
TOTALS	379	208	23	122	232	40	625	34

65 Outpatients

Table A-3 Mean basic sciences unit population

(24 HOUR PERIOD) MONDAY — FRIDAY

STATION	DOCTORS PROFESSORS SUPERVISORS	SECRETARIES CLERKS	TECHNICIANS LAB ASS'T	NURSES AIDS	JANITORS MAIDS	TOTAL STAFF	VOLUNTEERS STUDENTS
41	69	25	0	0	1	95	34
42	30	0	32	0	1	63	164
TOTAL	99	25	32	0	2	158	198
31	35	8	4	0	1	48	74
32	48	2	26	0	1	77	154
TOTAL	83	10	30	0	2	125	228
21	35	15	42	0	1	93	136
22	33	1	55	0	1	90	76
23	1	2	9	0	0	12	-
TOTAL	69	18	106	0	2	195	212
11	43	42	12	0	3	100	164
12	72	2	37	1	4	116	216
TOTAL	115	44	49	1	7	216	380
G1	14	7	24	0	1	46	15
G2	20	0	36	0	1	57	36
G3	6	0	22	0	2	30	-
G4	1	0	12	0	0	13	-
G5	2	0	18	0	0	20	-
TOTAL	43	7	112	0	4	166	51
Building Total	409	104	329	1	17	860	1069

Table A-4 Mean daily waste production

	HOSPITAL		BASIC SCIENCES		MEDICAL CENTER	
	Mon-Fri.	Sat.-Sun.	Mon.-Fri.	Sat.-Sun.	Mon.-Fri.	Sat.-Sun.
Bed Patients	402	379	-	-	402	379
Out Patients	376	65	120	-	496	65
Professional & Staff	1201	625	860	-	2061	625
Volunteers & Students	142	34	1069	-	1211	34
Gross Population*	2121	1103	2049	-	4170	1103
Average 8 Hour** Population Census	912	609	663	-	1575	609
Equivalent Population***	825		473		1298	
Disposable Waste	3300		1400		4700	
lb./Bed Patient	8.2	8.7	-	-	11.7	12.4
lbs./Person-Gross Pop.	1.6	3.0	0.7	-	1.1	4.3
lbs./Capita-Equiv. Pop.	4.0		3.0		3.6	
Reusable Wastes	9630		510		10140	
lbs./Bed Patient	24.0	25.4	-	-	25.2	26.7
lbs./Person-Gross Pop.	4.5	8.7	0.2	-	2.4	9.2
lbs./Capit-Equiv. Pop.	11.7		1.1		7.8	
Total Wastes	12930		1910		14840	
lbs./Bed Patient	32.1	34.1	-	-	36.9	39.2
lbs./Person-Gross Pop.	6.1	11.7	0.9	-	3.6	13.5
lbs./Capita-Equiv. Pop.	15.1		4.0		11.4	

* Sum of Patients, Out Patients, Doctors, Staff and Volunteers

** Sum of Patients plus 1/3 (sum of staff, volunteers and 1/2 out patients)

*** Equivalent Population Equals 5/7 M-F census plus 2/7 S-S census

Formulas Based on Los Angeles County Study (32)

Table A-5 Solid waste production rate calculations
(Monday-Friday)

UNIT	MEAN WEIGHT	PATIENTS	PAID STAFF	VOLUNTEERS STUDENTS	GROSS POPULATION	EQUIVALENT POPULATION*	LBS.PER PATIENT	LBS.PER GROSS POP.	LBS.PER EQUIV. POP..
MATA.	25.2	10	19	3	32	17.3	2.5	0.8	1.5
PSYC.	29.4	24	28	9	61	36.3	1.2	0.5	0.8
8th	54.6	34	47	12	93	53.7	1.6	0.6	1.0
GMED.	93.2	43	53	2	98	61.3	2.2	1.0	1.5
GMED.	89.8	47	67	2	116	60.0	1.9	0.8	1.5
7th	183.0	90	120	4	214	121.3	2.0	0.9	1.5
PED.	103.7	41	75	12	128	70.0	2.5	0.8	1.5
GYN.	90.2	44	63	3	110	66.0	2.1	0.8	1.4
6th	193.9	85	138	15	238	136.0	2.3	0.8	1.4
SURG.	203.5	46	52	1	99	63.7	4.4	2.1	3.2
SURG.	179.1	46	57	2	105	65.7	3.9	1.7	2.7
5th	382.6	92	109	3	204	129.3	4.2	1.9	3.0
OB.	96.2	15	37	9	61	30.3	6.4	1.6	3.2
ORTH.	74.8	21	28	3	52	31.3	3.6	1.4	2.4
ORTH.	94.2	38	40	4	82	53.7	2.5	1.1	1.8
OR.	191.3	19	79	0	93	45.3	10.0	2.0	4.2
IC.	110.0	8	43	1	52	22.7	13.8	2.1	4.8
3rd.	470.3	86	190	8	284	153.0	5.5	1.7	3.1

Table A-5 (continued)

UNIT	MEAN WEIGHT	PATIENTS	PAID STAFF	VOLUNTEERS STUDENTS	GROSS POPULATION	EQUIVALENT POPULATION*	LBS.PER PATIENT	LBS.PER GROSS POP.	LBS.PER EQUIV. POP.
X-RAY	77.0	0	35	22	57	19.0	0	1.4	4.1
BLAB.	231.1	0	46	16	62	20.7	0	3.7	11.2
REGM.	11.1	0	12	0	12	4.0	0	0.9	2.8
ENT.	8.8	0	20	2	22	7.3	0	0.4	1.2
CP.	33.6	0	29	5	34	11.3	0	1.0	3.0
EMG.	1.7	0	4	0	4	1.3	0	0.4	1.3
2nd	363.3	0	146	45	191	63.7	0	1.9	5.7
ER.	32.5	65	29	1	95	20.8	0.5	0.3	1.6
CLN.	66.4	311	113	19	443	95.8	0.2	0.2	0.7
ADMN.	82.8	0	66	20	86	278.7	0	1.0	2.9
CAFE.	25.0	0	6	0	6	2.0	0	4.2	12.5
GIFT.	14.4	0	2	6	8	2.7	0	1.8	5.3
1st	223.1	376	216	46	638	150.0	0.6	0.3	1.5
GRND.	128.0	0	25	0	25	8.3	0	5.1	15.4
DIET.	40.3	0	27	0	27	9.0	0	1.5	4.5
KITN.	1412.0	402	73	0	73	426.3	3.5	193.4	3.3
GRND.	1580.3	402	125	0	125	443.7	3.9	12.6	3.6
PHCY.	30.4	0	8	0	8	2.7	0	3.8	11.3
LAUN.	41.7	0	25	0	25	8.3	0	1.7	5.0
CENT.	98.3	0	9	0	9	3.0	0	10.9	32.8
COBT.	5.1	0	7	0	7	2.3	0	0.7	2.2
ALF.	15.3	0	24	0	24	8.0	0	0.7	2.0
BASE.	191.2	0	73	0	73	24.3	0	2.6	7.9

$$\text{Equivalent Population} = \text{patients} + \frac{1/2\ \text{outpatients} + \text{paid staff} + \text{volunteer}}{3}$$

Table A-6 Soiled linen quantities

Weight in pounds

DATE 1968	WEIGHT	DATE 1968	WEIGHT	DATE 1968	WEIGHT
June 24	10,750	June 1	8,400	July 8	10,035
June 25	6,345	June 2	6,600	July 9	7,850
June 26	7,520	June 3	6,100	July 10	7,835
June 27	7,128	June 4	-----	July 11	8,000
June 28	6,555	June 5	9,300	July 12	6,635
June 29	5,250	June 6	7,250	July 13	5,570
June 30	-----	June 7	-----	July 14	-----
Total	43,548	Total	37,650	Total	46,235
Mean	7,258	Mean	7,530	Mean	7,706
July 22	9,950	July 29	10,215	Feb. 10	10,725
July 23	8,360	July 30	7,687	Feb. 11	7,790
July 24	7,200	July 31	8,075	Feb. 12	7,150
July 25	8,700	Aug. 1	7,955	Feb. 13	8,332
July 26	8,780	Aug. 2	8,045	Feb. 14	7,914
July 27	6,970	Aug. 3	6,045	Feb. 15	7,550
July 28	-----	Aug. 4	-----	Feb. 16	-----
Total	49,960	Total	48,022	Total	49,461
Mean	8,327	Mean	8,004	Mean	8,244
Mar. 10	10,890	Apr. 28	11,650	May 5	10,285
Mar. 11	6,737	Apr. 29	7,100	May 6	6,780
Mar. 12	6,631	Apr. 30	8,036	May 7	7,189
Mar. 13	8,795	May 1	8,410	May 8	7,470
Mar. 14	7,945	May 2	7,705	May 9	7,222
Mar. 15	6,792	May 3	6,327	May 10	6,710
Mar. 16	-----	May 4	-----	May 11	-----
Total	47,790	Total	49,228	Total	45,656
Mean	7,965	Mean	8,205	Mean	7,609

Table A-6 (continued)

DATE	WEIGHT	DATE	WEIGHT
Jan. 68	192,692	Jan. 69	204,292
Feb. 68	188,612	Feb. 69	195,166
Mar. 68	208,543	Mar. 69	202,454
Apr. 68	211,488	Apr. 69	206,594
May 68	212,569	May 69	194,163
June 68	183,801	June 69	189,222
July 68	208,712	July 69	211,103
Aug. 68	208,156	Aug. 69	199,373
Sep. 68	190,562	Sep. 69	197,723
Oct. 68	210,604	Oct. 69	206,957
Nov. 68	196,227	Nov. 69	181,777
Dec. 68	177,597	Dec. 69	196,295
Total	2,389,563	Total	2,385,069
Mean Day	7,835	Mean Day	7,820

APPENDIX B

Appendix B consists of the Chemical Test Procedures

TEST FOR MOISTURE
(Oven Drying Method)

Equipment:

Drying oven
Large glass desiccator (250mm sufficient)
Sample containers (covered aluminum cans)
A balance (graduated to 0.1 grams sufficient)

Procedure:

1. Preheat drying oven to 103°C.

2. Duplicate samples of 50 - 100 grams of freshly ground refuse are placed in tared sample containers and immediately cover. (1) Remove and discard inorganic materials such as glass, metal, and ceramics before grinding; (2) Do not pack the material.

3. Weigh the samples to the nearest decigram (0.1 gm) within one hour.

4. Dry the material to a constant weight being sure to have the container lid cocked off. Note: the oven temperature should be 75°C, unless removal of volatile constituents such as ammonia-N and liquids are desired, in such case the oven temperature should be raised to 103°C.

5. Allow samples to dry for 48 hours.

6. Cool samples in dry area or desiccator and then weigh.

Calculation:

$$\text{Percent moisture (wet basis)} = \frac{100\text{ (loss in weight)}}{\text{(net wet weight)}}$$

VOLATILE SOLID AND ASH TEST

Equipment:

Drying oven
Analytical balance
Desiccator
Procelain crucibles (high form)
Muffle furnace with indicating pyrometer and rheostat temperature control

Procedure:

1. Transfer 3 to 6 grams of dried and ground sample to a previously ignited and tared crucible.
2. Re-dry samples for 2 hours at 75°C and weigh to nearest centrigram (0.01 gm)
3. Place the crucibles in a cold muffle furnace and gradually bring the temperature to 600°C with door raised about 1/2 inch.
4. Muffle at 600°C for 2 hours.
5. Cool in a desiccator and weigh.

Calculations:

(a) Percent ash =

$$\frac{100\ (\text{tared sample left after firing})}{(\text{net dry weight})}$$

(b) Percent volatile solids = 100 - percent ash

TEST FOR GROSS CALORIFIC VALUE

Equipment:

Parr oxygen bomb calorimeter (adiabatic calorimeter)
Parr oxygen double valve bomb
Parr automatic electric water heater
Parr ignition unit (transformer type)
Parr metal combustion capsules
Support stand for oxygen bomb heads
Parr oxygen filling connection
Oxygen cylinder (standard commercial or medical grade whichever is more convenient)
Analytical balance
Pressure regulator (standard commercial)

Reagents:

Distilled water
Sodium carbonate solution, 0.0725N: dissolve 3.84 grams of Na_2CO_3 in distilled water and dilute to one liter
Sodium hydroxide or potassium hydroxide solutions of the same normality are acceptable
Methyl orange or methyl red indicator

Procedure:

1. Attach a single length of 10 centimeters of standard fuse wire between the electrodes of the oxygen bomb head.

*2. Weigh 0.8 to 1.2 grams (never more than 1.5) of the redried sample directly into a metal combustion capsule. Place the capsule in the loop holder on the bomb head and bend the center of the fuse wire down so that it is set slightly above the surface of the material in the capsule.

3. Put 1 milliliter of distilled water in the bomb from a pipette; put the bomb head into the cylinder; Place contact ring above the sealing gasket; screw the cap down firmly by hand.

4. Attach the filling connection to the bomb inlet valve and slowly admit oxygen to between 25-30 atmosphere gage pressure at room temperature. Note: If too much oxygen should accidently be introduced, do not proceed with combustion, exhaust the bomb.

*5. Fill the calorimeter bucket with 2,000 grams (+ or - 0.5 grams) of distilled water, which may be measured volumetrically instead of weighing if it is always done at the same temperature. Note: The temperature of water should be 3° or 4° below that of the room.

6. Set the filled bucket in the calorimeter jacket: lower the bomb into the water, taking care to avoid jarring or disturbing the contents. Attach the thurst terminal to the bomb electrode and shake back into the bucket all drops of water adhering to the fingers.

7. Swing the cover on the jacket with the thermometer toward the operator. Lower the cover into position, using care to avoid striking the thermometer against anything. Put on the rubber drive belt and start the motor. (Should turn at 150 clockwise revolutions per minute; most motors are pre-adjusted to this speed)

8. Run the motor for 5 minutes to attain thermal equilibrium but do not record temperatures during this period. Adjust the thermometer reading lens and be prepared to take temperature readings as soon as equilibrium is indicated by a slow, uniform rise.

9. Then press the botton on the ignition unit to fire the charge at the start of the sixtieth minute, recording the exact time and temperature at the firing point.

10. After the period of rapid rise (about 4 or 5 minutes after firing) adjust the reading lens and record the temperatures to the nearest 0.01°F when the reading has been constant for 5 minutes. Usually the temperature will reach a maximum then drop slowly.

11. The net rise is equal to the difference between the initial temperature at the time of firing and the final maximum temperature developed in the calorimeter.

12. After completing the readings, stop the motor, remove the belt, and swing the cover from the jacket; wipe the thermometer bulb with a clean cloth to remove any water, and set the cover on the support stand; disconnect the firing connection from the bomb terminal.

13. Lift the bomb out of the bucket and relieve all residual pressure.

14. After all pressure has been relieved, remove the cap, lift out the bomb head and place it on the support stand. Examine the interior of the bomb for soot or other evidence of incomplete combustion, and discard the test if any is found.

15. Wash all interior surfaces of the bomb with a jet of distilled water and quantitatively collect the washings in a beaker. Titrate with 0.0725N alkali solution, using methyl orange or methyl red. Save the solution remaining after titration for determining the sulfur content of the sample.

16. Carefully remove all unburned pieces of fuse wire from the bomb electrodes, straighten them and measure their combined length in centimeters. Subtract this length from the initial 10 centimeters, and enter this value on the data sheet as the net amount of wire burned.

17. Repeat the same procedure for each succeeding test.

* Indicates changes made in the original testing procedures.

Calculations: The following data should be available at the completion of a test using the calorimeter.

a = Time of firing

b = Time (nearest 0.1 min.) when the temperature reaches 60 percent of the net rise.

C = Time at beginning of period (after the temperature rise) in which the rate of temperature change has become constant.

t_a = Temperature at time of firing.

t_c = Temperature at time of temperature attaining constant.

r_1 = Rate at which temperature was rising during the 5 minute period before firing (degree F per minute)

r_2 = Rate at which the temperature was falling during the 5 minute period after time C (degrees F per minute). If the temperature was rising instead of falling after time C, subtract the quantity r_2 (c-b) instead of adding it when computing the correct temperature rise.

C_1 = Milliliters of 0.0725N alkali solution used in the acid titration.

C_2 = Percentages of sulfur in the sample.

C_3 = Centimeters of fuse wire consumed in firing.

W = Energy equivalent of the calorimeter (supplied by the manufacturer) in calories per degree Fahrenheit. (1356 cal/F°)

m = Mass of sample in grams.

$t = t_c - t_a - r_1 (b-a) + r_2 (c-b)$

$e_1 = C_1$ if 0.0725N alkali was used for titration.

$e_2 = (14)\ C_2\ (n)$

$e_3 = (2.3)\ (C_3)$ when using Parr 45C10 nickle - chromium fuse wire or

$= (2.7)\ (C_3)$ when using No. 34 B & X gage iron fuse wire.

Hg = Gross calorific value

$$Hg - \frac{tw - e_1 - e_2 - e_3}{m}$$, calories per grams,

calories per gram (1.8) = B.T.U. per pound

TEST FOR SULFUR

Equipment:

Parr oxygen bomb calorimeter
Oxygen cylinder (standard commercial)
Pressure regulator (standard commercial)
Steam bath or hot plate
Crucibles
Muffle furnace (600 to 900°C)
Drying oven
Desiccator
Analytical balance
beakers (400 ml and 250 ml)
Filter paper-ashless (Whatman 41 and 42)
Fluted watch glasses
Volumetric pipettes

Reagents:

Wash Water
Methyl orange indicator: one milliliter saturated solution of methyl orange indicator per liter of distilled water
Concentrated ammonium hydroxide
Concentrated hydrochloric acid
Saturated bromine solution
Barium chloride solution (10 percent)

Procedure:

1. Collect the bomb washings following (see test for gross calorific value) the combustion of a sample not weighing more than one gram. Note: If the sample has not been used for a calorimetric test, allow the bomb to stand in a water bath at least ten minutes after firing.

2. Release the residual gases slowly and at an even rate so that the pressure is reduced to atmosphere in not less than one minute.

3. Wash all the interior parts of the calorimeter with wash water and collect the washings in a beaker or Erlenmeyer flask (250 ml is sufficient). Note: Wash until no further acid reaction is observed and be sure to add all precipitate to the beaker.

4. Titrate the washings with standard sodium carbonate solution (0.0725N, see test for gross calorific value) to determine the acid correction.

5. After neutralization, add one milliliter of NH_4OH (concentrated ammonium hydroxide), heat the solution to boiling, and filter through rapid filter paper (Whatman #41) into a 600 or 400 milliliter beaker.

6. Wash the filter paper and residue with hot distilled water.

7. Add sufficient water to the beaker to bring the total volume of solution to approximately 250 milliliters.

8. Neutralize the solution with concentrated HCl and add two milliliters in excess. Note: Approximately three milliliters will be sufficient.

9. Add ten milliliters of saturated bromine water.

10. Evaporate the solution to approximately 200 milliliters on a hot plate or other source of heat.

11. Add ten milliliters of 10% barium chloride to the solution slowly while stirring.

12. After two minutes of stirring, cover the beaker with a fluted watch glass and reduce the volume to 75 milliliters on a hot plate or other source of heat.

13. Allow the precipitate to settle and cool. Note: Cooling period may be from one to twelve hours depending on the sample being tested.

14. Filter the barium sulfate precipitate through ashless filter paper (Whatman #42).

15. Wash the filter paper with warm water until you are sure it is free of chlorides.

16. Transfer the filter paper containing the precipitate to a previously dried and weighed crucible.

17. Dry and char the filter paper at low heat without flaming.

18. Place the crucible containing the filter paper in a muffle furnace and raise the temperature to 600°C.

    Note: Allow the crucible to stay in the muffle furnace for 2 hours after the 600°C temperature has been reached.

19. Cool in desiccator until room temperature is reached.

20. Re-weigh the crucible.

21. Determine weight of the barium sulfate precipitate .

Calculations:

$$\text{Percent Sulfur} = \frac{\text{weight of } BaSO_4 \text{ X } 13.734}{\text{weight of sample}}$$

TEST FOR PHOSPHORUS

Equipment:

Micro Kjeldahl flasks
Fume hoods
Volumetric flasks
Spectrophotometer or calorimeter
(equipped with a light filter with maximum transmittance near 625 to 675 millimicrons)
Drying oven
Desiccator
Analytical balance
Columetric pipettes

Reagents:

Sulfuric acid (93 to 96 percent H_2SO_4)
Concentrated nitric acid
*Perchloric acid (70 percent)
Ammonium molybdate solution: dissolve 5 grams of ammonium molybdate in 10 milliliters of concentrated sulfurnic acid and make up to one liter
Elon solution: dissolve 10 grams of elon in one liter of 3 percent $NaHSO_3$
Standard potassium dihydrogen phosphate solution: dissolve 1.917 grams of pure dry KH_2PO_4 in water and dilute to one liter. (One milliliter of this solution is equivalent to 1 milligram of P_2O_5)

Procedure:

1. Weigh out approximately 0.5 grams of redried sample in previously dried and tared sample container.

*2. Transfer the sample to a micro Kjeldahl flask and add about 2 milliliters of concentrated HNO_3, 2 milliliters of perchloric acid, and 1 milliliter of concentrated H_2SO_4.

3. Heat slowly at first and ther strongly until the solution becomes clear.

4. Cool rinse into a flask and make up to 100 milliliters.

5. Pipette 1 milliliter (or any suitable aliquot) of this solution into a test tube, add 3 milliliters of molybdate solution and 1 milliliter of elon solution, (5 milliliters total volume)

6. Pipette a measured portion of standard phosphate solution into a test tube, add the same amount of molybdate and elon solution and dilute to the mark with water.

*Indicates changes made in the original test procedures.

7. Mix the sample and standard thoroughly and allow to stand for 30 minutes.

8. Read and compare samples in a calorimeter.

Calculations:

Say X ug is the concentration read from the calorimeter.
1 ml. contains X ug
100 ml. 100 ug

This 100 ml. has been extracted from 0.5 grams of sample
0.5 grams contains 100 C ug

$$\frac{100X}{0.5} \times \frac{100 \text{ gms.}}{10^6}$$

$$= \frac{X\%}{50}$$

PROCEDURE FOR CARBON-HYDROGEN ANALYSIS

Equipment:

Carbon Combustion Train - The apparatus consists of the following units arranged as listed in the order of passage of oxygen from the cylinder.

(a) Coarse Needle Valve -- The coarse needle valve is used to regulate a rough flow of oxygen through the system.

(b) Oxygen Purifying Train -- The purifying train consists of three units in the following order:

(1) Preheater -- The oxygen, before entering the combustion tube, is purified by passing it through a silica tube filled with copper oxide (wire form). The correct temperature for the preheater is 750°C which is controlled by a Steples input control variac.

(2) Water absorber -- A U-tube filled with drierite is used as an absorber of water that may exist in the oxygen.

(3) Carbon dioxide absorber -- A U-tube filled with ascarite is used to absorb carbon dioxide in oxygen directly from the cylinder.

(c) Fine Needle Valve -- A fine needle valve is used for adjustment of the oxygen flow through the system.

(d) Flow Meter -- Used to permit a volumetric measurement of flow of oxygen during analysis. The flow rates are 50 - 75 ml per minute or 2 - 3 bubbles per second in the bubbler at the end of the train.

(e) Combustion Unit -- The combustion unit consists of three electrically heated furnace sections. Each section is individually controlled by two dials labeled "coarse" and "fine".

Furnace Section 1 -- This furnace section, nearest the oxygen inlet end of the combustion tube, is approximately 12 inches long and is used to heat the inlet end of the combustion tube and the sample. It is capable of rapidly attaining an operating temperature of 850° to 900°C.

Furnace Section 2 -- This section is approximately 8 inches in length and is used to heat that portion of the combustion tube that is filled with copper oxide. The operating temperature is 850° ± 20°C.

Furnace Section 3 -- This section is approximately 4 inches long and is used to heat that portion of the combustion tube filled with fused lead chromate.

(f) Combustion tube -- The combustion tube is a high temperature silica tube packed with copper oxide and fused lead chromate which aid in the oxidation of gases flowing through the tube. The filling also contains copper metal.

(g) Combustion Boat -- The boats are approximately 70 x 8 x 8 mm and are of porcelain material with micro carbon content.

(h) Absorption train -- The absorption train consists of two Nesbitt absorption bulbs. The first bulb is filled with drierite for removal of water and the second, ascarite for CO_2 absorption.

(i) Water Bubbler -- A 100 ml. bubbler is connected to the ascarite Nesbitt bulb. The bubbler is constructed in such a manner that glass tubing is submerged in water in the bubbler. This gives the operator some idea of the flow through the combustion train. The average flow should be 50 to 70 ml. per minute or 2 to 3 bubbles per second.

Reagents and Accessory Equipment:

Tank of highly purified carbon dioxide
Ascarite
Drierite
Analytical Balance
Dessicator
Combustion Rake

Procedure:

To begin a series of analysis, attach all Nesbitt bulbs in correct positions and regulate the oxygen by adjusting needle valves to the corresponding combustion train. Adjust the flow of oxygen to 50 - 70 ml./min. or 2 - 3 bubbles per second, which is the correct flow for analysis.

After regulating the oxygen, energize heater section 2 to 850 ± 20°C and section 3 to 500 ± 50°C. It will take about 90 minutes to reach these temperatures. When the temperatures are reached, they will be maintained throughout the entire procedure.

Remove the Nesbitt bulbs from the train, wipe them with a clean cloth and cool them to room temperature. While these are cooling, the sample can be weighed in the combustion boat and placed in a dessicator. (Refuse samples are weighed to 0.2 gram). After the Nesbitt bulbs have cooled, open the bulbs for a moment to allow them to reach atmospheric pressure, weigh them, and replace them to the correct positions on the combustion train. Transfer the combustion boat containing the sample to the transparent section of the combustion tube.

A rod called a comb. rake is used to remove the combustion boats and to place them in their correct positions in the combustion tube. Furnace section 1 is energized and moved from the left end of the track to cover about half of the boat containing the sample. If furnace section 1 has been cooling from a previous test, its temperature should be below 200°C. before another test is started. The temperature is gradually increased to 850 to 900°C. so that the sample burns slowly and evenly. If the sample is highly volatile cooling to room temperature may be required.

During this time, furnace section 1 is moved slowly toward furnace section 2 until the sample is completely covered by furnace section 1. (This process takes about 40 to 50 minutes for a refuse sample). After full heat is reached, hold in this position for 15 minutes. Furnace section 1 is then returned to the starting position and its temperature is reduced to the starting position and its temperature is reduced to below 200°C. The oxygen flow is continued for at least 15 to 20 minutes or longer if water vapor exists in the tubing at the end of the combustion tube. The Nesbitt absorption bulbs are closed under pressure and removed from the train and placed near a balance for 15 to 20 minutes and then wiped clean with a lint free cloth. The Nesbitt bulbs are vented momentarily and their weights are recorded. Calculate the percent carbon and hydrogen. The percent ash can also be determined by weighing the combustion boat again and calculating the weight of ash.

**The temperatures and combustion fillings for each combustion section were obtained from The American Society of Testing Materials, Book of A.S.T.M. Standards, Part 5 (Philadelphia: The Society 1952).

Calculations:

$$\% \text{ carbon} = \frac{\text{wt. increase of } CO_2 \text{ absorber} \times \frac{\text{MW of C}}{\text{MW of } CO_2} \times 100}{\text{sample weight}}$$

$$= \frac{\text{wt. increase of } CO_2 \text{ absorber} \times 27.29}{\text{sample weight}}$$

$$\% \text{ hydrogen} = \frac{\text{wt. increase of water absorber} \times \frac{2 \times \text{MW of H}}{\text{MW of } H_2O} \times 100}{\text{sample weight}}$$

$$= \frac{\text{wt. increase of water absorber} \times 11.17}{\text{sample weight}}$$

$$\% \text{ ash} = \frac{\text{wt. of ash} \times 100}{\text{sample weight}}$$

PROCEDURE FOR OPERATION OF COLEMAN NITROGEN ANALYZER II

I. Sample Preparation

a. Add the proper amount of sample to a previously weighed combustion boat and weigh to determine amount of sample. Amount of sample used should depend on the theoretical yield of nitrogen of sample. Consider 1 mg nitrogen displaces 1000 microliters in the analyzer. Samples sized to release between 12-15,000 microliters give best results. Combustion boat should then be filled with Cuprox fires to give good reagent-sample mixture.

b. Fill a Quartz Combustion Tube to the top of the trademark with Cuprox, the trademark being at the end upper. Tap the tube to settle the Cuprox to the bottom of the trademark.

c. Turn the tube until it is horizontal and carefully insert the loaded sample boat into the open end. Slide or push the boat without spilling it's contents, until it reaches the Coleman trademark.

d. After the boat is introduced add enough Cuprox to just cover the combustion boat. Tap the tube gently to integrate the contents of the combustion boat and Cuprox.

e. Raise the open end to an angle 60-70° with horizontal and add Cuprox to within 3/4" from the top of the tube. Tap or vibrate to eliminate spaces.

II. Machine Preparation

a. Connect the side arm and central capillary tubes to the inlet and syringe tubing with the spring clamps.

b. Turn the CO_2 tank valve on, adjust the Regulator to 12 psi and then open the line. If the pressure gauge on the front panel of the machine does not read 12 psi, adjust by the regulator gauge.

c. Turn the line switch on and the upper and lower furnace controls to 3; the post heater control to 10. Allow at least 20 minutes for the furnaces to warm up. Upper and lower furnaces should read 700°C and the post heater should read 600°C.

d. Insert the combustion tube by placing the upper end firmly against the upper tube support and riase the upper support against its spring until the lower end of the tube can be slipped into the opening of the lower support. Release of the upper support will firmly clamp the tube in place.

e. Adjust the meniscus level of liquid in the nitrometer to the calibration mark of the central capillary tube. Great care must be used in doing this to avoid running the caustic liquid above the o-ring connection to the syringe. Final adjustment must be made with the manual fine adjust wheel. It is also imperative that the readout counter never be driven above 50,000. This will permanantly damage the syringe. Proper level and counter reading can be obtained by aid of the vent control. Take the reading on the counter.

f. Record the syringe temperature and the barometric pressure.

g. Turn the combustion cycle control to the start segment line and allow the automatic combustion cycle to proceed.

h. After the cycle is complete, readjust the causticon level and record the readout counter setting.

Record the temperature (if the temperature rise is more than .8°C the test in results are void. This is usually avoided by running 3 to 4 blank cycles at the beginning. The barometric pressure is assured to remain unchanged during the test run. These are the data used in calculating the % yield.

A blank must be run prior to testing to determine the volume of unabsorbed gas which appears as a result of a combustion cycle, but which originates from other sources other than a weighed sample.

NOTE: These are only the basic essentials of operation and do not cover much of the preparation of the machine and reagents. One should read the instruction manual to gain full understanding of the machine.

Equipment:

Coleman Nitrogen Analyzer II
Tank of highly purified CO_2
Mercury Barometer, accurate and readable to 0.5 mm Hg.
Analytical Balance
Coleman aluminum combustion boats
Coleman quartz combustion tube and quartz postheater tube
Dessicator
Tweezers
Glass rod 7/16" x 15"

Reagents:

Coleman CUPROX or CUPROX Platinum Catalyst
Coleman CUPRIN
Coleman CAUSTICON (KOH)
Mercury

F. Calculation

1. Record the observed volume of nitrogen, V_o

$V_o = R_2 - R_1$

V_o = Observed N Volume (μl)
R_1 = Initial Counter Reading
R_2 = Final Counter Reading

2. Determine the corrected nitrogen volume, V_c (in microliters)

$V_c = V_o - (V_b + V_t)$

V_b = Volume of Blank (μl)
V_t = Volume correction for temperature (μl)
$= C_f(t_2 - t_1)$
C_f from table 1 (based on final counter reading)
t_2 and t_1 in ° C (IV, D, 4 and 6)

3. Determine the corrected barometric pressure, P_c

$P_c = P_o - (P_b + P_v)$

P_o = observed barometric pressure (mm Hg)
P_b = barometric temperature correction (TABLE 2)
P_v = pressure correction for vapor pressure of KOH from TABLE 3

Note: An empirical approximation of $(P_b + P_v) = 11.0$ will be satisfactorily accurate for P_o between 740 and 780 mm Hg and syringe temperature 25 and 32° C.

4. Calculate % N from the formula:

$$\%N = \frac{P_c}{T} \times \frac{V_c}{W} \times 0.0449$$

T = Final Syringe Temperature in °Kelvin (°C + 273)

W = Sample weight in milligrams.

Example:

P_o = 750 mm Hg
W = 498.5 mg

	Start	Finish
Counter readings, Blank	500 μl	524 μl
Counter readings, Sample	524	17,207

t_1 = 27.5°C
t_2 = 27.7°C
V_o = 17,207 − 524 = 16683 μl
V_c = 16683 − (0024 + $C_f(t_2 - t_1)$)
= 16683 − (0024 + 68 × 0.2)
= 16646 μl
P_c = 750 − 11
= 739

$$\%N = \frac{739}{300.7} \times \frac{16646}{498.5} \times .0449$$

= 3.68%

TABLE 1

Volume Correction for Temperature

Correction Factor

(C_t)

(Microliters per °C)

Final Counter Reading (Microliters)	(C_t) (Nitrometers with check valve)
0	12
5000	29
10000	45
15000	62
20000	79
25000	95
30000	112
35000	129
40000	145
45000	162
50000	179

Volume correction, $V_t = C_t(t_2 - t_1)$

TABLE 2

Barometric Temperature Correction (P_b)

Temperature °C	P_o (mm Hg) 700-749	750-780
10	1.2	1.3
15	1.8	1.9
20	2.3	2.5
25	2.9	3.1
30	3.5	3.7
35	4.1	4.3

TABLE 3

Pressure Correction (P_v) for Vapor Pressure of KOH

Temperature °C	P_v (mm Hg)
15	4.1
20	5.7
25	7.4
30	9.6
35	12.5
40	16.5

APPENDIX C

Appendix C consists of the Bacteriological and Virological Test Procedures

Phase I Analyses

Bacto-Plate Count Agar (0479)

Tryptone Glucose Yeast Agar - This medium is recommended as a general plating medium for ascertaining bacterial populations. The clarity of the medium and the increased size of the colonies permit the determination of bacterial counts with ease.

To rehydrate the medium, suspend 23.5 grams of 1000 ml of cold distilled water. Heat to boiling to dissolve completely. Sterilize in autoclave for 15 minutes @ 15 psi (121°C).

Bacto-Nutrient Broth (B3)

Bacto-Nutrient Broth is recommended for general laboratory use for the cultivation of microorganisms that are not exacting in for requirements.

To rehydrate the medium, dissolve 8 grams of Bacto-Nutrient Broth in 1000 ml of distilled water. Distribute in tubes (10 ml/tube) and sterilize in the autoclave for 15 minutes at 15 pounds pressure (121°C).

Fluid Thioglycollate Medium (B256)

Bacto-Fluid Thioglycollate Medium is recommended for the sterility test of biologicals. Also, it has been recommended as a liquid medium for the cultivation of anaerobes. •

To rehydrate the medium, suspend 29.5 grams of Bacto-Fluid Thioglycollate medium in 1000 ml distilled water, and heat to boiling to dissolve the medium completely. Then, distribute into tubes, autoclave for 15 minutes @ 15 psi (121°C).

Violet Red Bile Agar (B12)

Bacto-Violet Red Bile Agar is recommended for the direct plate count of coliform bacteria in water, milk dairy products and wastes.

To rehydrate medium, suspend 41.5 grams of Agar in 1000 ml of cold distilled water and heat to boiling to dissolve medium completely. Cool to 40-44°C and pour plates.

Bacto MacConkey Agar (B75)

Bacto-MacConkey Agar is a differential plating medium recommended for use in the detection and isolation of type of dysentery, typhoid and para-typhoid bacteria for any material harboring these organisms.

To rehydrate the medium, suspend 50 grams of Bacto-MacConkey Agar in 1000 ml of cold distilled water and heat to boiling to dissolve the medium completely. Sterilize by autoclaving for 15 minutes @ 15 pounds pressure (121°C). MacConkey Agar inoculated the same day as rehydrated may be used without autoclave sterilization. Under these conditions the medium need be heated only to boiling to dissolve it completely before pouring into petri dishes.

Mannitol Salt Agar

Bacto-Mannitol Salt Agar is a selective medium for the isolation of pathogenic staphylococci. Growth of most bacteria other than staphylococci is inhibited on this medium. It is recommended for growth at 37°C for 36 hours.

To rehydrate the medium suspend 111 grams Bacto-Mannitol Salt Agar in 1000 ml cold distilled water, and heat to boiling to dissolve the medium completely, autoclave for 15 minutes @ 15 psi.

Blood Agar Base (B45)

Bacto-Blood Agar Base is recommended as a base to which blood is added for use in the isolation and cultivation of mainly fastidious pathogenic organisms. Colonies of bacteria upon this agar grow luxuriously and the hemolytic types exhibit clear distinct degrees of hemolysis.

To rehydrate the medium, suspend 40 grams of Bacto-Blood Agar Autoclave for 15 minutes @ 15 psi.

If blood Agar is to be prepared immediately, the sterile medium is cooled at once to 45-50°C., and while still liquid, 5 percent sterile defribrinated sheep blood is added aseptically with thorough mixing, avoiding incorporation of air bubbles, and distributing into sterile plates.

Bacto-Cooke Rose Bengal Agar

Cooke Rose Bengal Agar is a selective medium for the isolation of fungi. To rehydrate the medium, suspend 36 gr. Bacto-Cooke Rose Bengal Agar in 1000 ml distilled water. Heat to boiling to dissolve the medium completely and sterilize in the autoclave for 15 minutes @ 15 pounds pressure (121°C).

The selectivity of the medium was increased by the addition of: (1) Penicillin (1 ml for 500 ml media) and (2) Streptomycin (0.5 ml for 500 ml media). Both of these antibiotics are added to media after autoclaving with 2 ml syringes.

Mitis Salivarius Agar (B298)

Bacto-Mitis Salivarius Agar is for the isolation of Streptococcus Mitis S. Salivarius, and Enterococci. The final medium containing Bacto-Chapman Tellurite Solution, is highly selective for these organisms making possible their isolation from grossly contaminated specimens such as feces or exudates from different body cavities.

To rehydrate the medium, suspend 90 grams of Bacto-Mitis Salivarius Agar in 1000 ml cold distilled water and heat to boiling to dissolve the medium completely. Sterilize in the autoclave for 15 minutes at 15 psi (121°C). Cool to 50-55°C and just prior to pouring plates add exactly 1.0 ml of Bacto-Chapman Tellurite Solution. Prepare plates with 25 ml medium per plate. Do not heat the medium after the addition of the Tellurite Solution.

The preceding discussion of all types of agar is from the Difco Manual, 9th Edition.

TEST JOURNAL

July 14, 1970

Sample: Incinerator Room

Ground to 2 mm

- 1 gm + 9 ml (peptone phosphate diluent)

- Diluted and plated 0.1 ml surface spread

Inoculation: 10^{-3} - 10^{-8} 4 plates plate count Agar

2 incubated Aerobically

2 Incubated Anaerobically

10^{-1} - 10^{-6} 1 plate each

Violet Red Bile Agar

MacConkey Agar

All incubated Microaerophillicly MS Agar

Mannitol Salt Agar

Blood Agar

Cooke's Rose Bengal Agar

0.5 gm of ground sample + flask of EE Broth

0.5 gm of ground sample + flask of Aride Cactose Broth

All dilutions heated then heated @ 80-82°C for 30 minutes and 1 ml inoculated into each of:

3 Thioglycollate Broth

3 Nutrient Broth

July 15, 1970

Only those plates were read that had colonies that ranged from 30-300.

	Dilution	Total No. of Colonies	Remarks
Aerobic Plates (2)	10^{-4}	37, 53	10^{-4}, 10^{-5} (Reincubated)
Blood Agar	10^{-3}	-	overgrown with Bacillus
	10^{-4}	31	4 Coeyne bacterium No Hemolytic Colonies
MS	10^{-1}		Separate Colonies 5. Mitis (12 Colonies)
	10^{-2}	41	38 Black Colonies 3 Molds 10^{-2} (Reincubated)
VRB	10^{-2}	60	25 large, pink Bacilli, Some streptococci
MacConkey	10^{-2}	67	27 cocci-like Bacilli, Some Streptococci
MSA	10^{-4}	-	4 Staphylococci Too good for Bacilli

Thioglycollate 10^{-1} - 10^{-5}: 3(+), -10^{-6}: 2(+) 1(-), 10^{-7} 1(+) 2(-), 10^{-8}: 3(-)

Nutrient Broth 10^{-1} - 10^{-5}: 3(+), 10^{-6} 2 (+) 1(-), 10^{-7}: 3(-), 10^{-8}: 3(-)

EE Broth to VRB and MacC
Azide Lactose Broth to MS and BA

July 15, 1970

Pink colonies picked (2) from MacC and (2) from VRB to start for confirmation

Mac	1	Poss. Coci
	2	Less Poss. coci
VRB	3	Poss. coci
	4	Less Poss. coci
MS	5	Poss. enterococci
	6	Poss. Streptococci
BAP	7	Staphylococci

Gram Stain

MS:	Black Colonies	oval and (+) cocci	? Enterococci
	Deep Blue Colonies, Small	Round and Var. Sizes	
	Large Pale Blue Colonies	small and cocci short chains	? Staph/Strep
BAP	Very small grey	small, irreg.(+) rods	? Corynebacterium
	Med. White, flat, smooth, round	round (+) cocci	Staph +1
	Round, shiny, flat, yellowish	large (+) rods very reg. width	- Bacillus
PCA	Large, Dull, flat white	large (+) rods, var. length	Bacillus
	Large, dull, flat, grey	long (+) rods	"

Juicy and Medium	Mod. size, reg. (+) rods	Bacillus
Very diffuse	Mod, size, very reg (-) rods	?
Very, reg. large	Mod.size, (+) rods	Bacillus
Med. wrinkled	(+) and (-) rods and filamentous reg. width	"

Therefore, Total Count - Mostly Bacillus
5-10% Staphylococcus
5-10% Corynebacterium

July 16, 1970

Anaerobic plates 10^{-4} look like aerobic (Bacillus and Staph.)

Aerobic plates overgorwn and discarded

Plates for EE Broth and Azide Lactose Broth are (+) cocci and fecal Strep. (Entracoccus)

CRB $10^{-1.3}$ Total 59
19 ? Fumigatus
7 Yeast

July 20, 1970

Standard anaerobic counts 7-14-70

10^{-4} 28;23

Thioglycollate 10^{-5}: 3(+) 10^{-6}: 2(+) 10^{-7}: 1(+) - 1.5×10^6/gm

Nutrient Broth 10^{-5}: 3(+) 10^{-6}: 2(+) 10^{-7}: 0 - 9.3×10^5/gm

Fungus - Alternaria, Phytomycetes
Blue-Green Aspergillis, Pencillin Types
Yellow-Green Aspergillus

July 21, 1970

Samples (2)

1. Blood Bank
2. Incinerator Room

Set up same as 7-14-70 except 1 anaerobic plate and no flasks of EE Broth and Azide Cactrose Broth

		Dilution	Total No. of Colonies	Remarks
Aerobic Sample	No. 1(2)	10^{-3}	87, 110	Mixed Bacillus with 5% Staphylococcus reincubated (10^{-3} + 10^{-4})
	No. 2(2)	10^{-4}	94,92	Mostly, regular flat mat colonies: Bacillus

	1	2
MacC	10^{-1} Pink 24 Total 97 Except Bacillus	13 53
VRB	10^{-1} Pink 13 Total 64	13 52
MS	10^{-1} 23 Black 7 Blue	17 Black 0 Blue
BAP	10^{-3} 104 very mixed looked like Enterococcus 10^{-4}	77 Predominate colonies greenish and Hemolytic BA
MSA	10^{-2} 13 Staph like	33 Staph like

Preiled colonies to lactose broth (1) MacC 8
VRB 9, 10

(2) MacC 11, 12, 13
VRB 14, 15, 16, 17

(1) N. Broth 10^{-4} 3(+) 10^{-5} 2(+) 10^{-6} 0(+)

Thioglycollate 10^{-5} 3(+) 10^{-6} 2(+) 10^{-6} 0(+)

(2) N. Broth 10^{-4} 3(+) 10^{-5} 2(+) 10^{-6} 0(+)

Thioglycollate 10^{-5} 3(+) 10^{-6} 1(+) 10^{-7} 0(+)

July 23, 1970

Anaerobic Counts		Dilution	Colonies
	(1)	10^{-3}	16
	(2)	10^{-4}	71
Rose Bengal	(1)	10^{-1}	mold: 22
			yeast: 20
	(2)	10^{-1}	mold: 110
			yeast: 69

Colonies picked to Lactose Broth on July 22, Read on July 24

8. gas...BGBLB +
9. gas...BGBLB +
10. ---
11. ---
12. gas...BGBLB +
13. Little gas... BGBLB +
14. ---
15. gas...BGBLB +
16. ---
17. ---

Colonies picked from July 14, all lactose Broth (-)

Triple Sugar Iron(TSI)

1. Acid & gas/butt & slant
2. Alkaline slant,butt no
3. as 1
4. as 2

1. M-S Black colonies.....N.A. slant # 18 &19
2. M-S Black colonies.....N.A. slant # 20 & 21
3. B.A. ? Staph. N.A. slant # 22

B.A. ? Staph. citrius N.A. slant # 23

? B. cercus N.A. slant # 24

July 25, 1970

Aerobic Counts (after 15 hours)

	dilution	Colonies
(3)	10^{-2}	10, 12
(4)	10^{-2}	66
	10^{-3}	8

	(3)		(4)	
M-S	10^{-1}	no growth	10^{-1}	no growth
MSA	10^{-1}	no growth	10^{-1}	no growth
MacC	10^{-1}	17	10^{-1}	no growth
VRB	10^{-1}	25	10^{-1}	no growth
B.A.	10^{-1}	25	10^{-2}	81

July 27, 1970

Cooke's Rose Bengal from July 21

(1) Yeasts, phycomycetes, Aspergillus, and green,velvet colonies

(2) Similar to (1)

Cooke's Rose Bengal from July 24

(3) 10^{-1}: 2 colonies above background

(4) 10^{-2}: 66 colonies 2 as background

(1) Thioglycollate: 10^{-5}: 3+, 10^{-6}: 2+, 10^{-7}: 3-

Nutrient Broth: 10^{-5}: 3+, 10^{-6}: 1+, 10^{-7}: 3-

(2) Thioglycollate: 10^{-5}: 3 +, 10^{-6}: 1 +, 10^{-7}: 3 -

Nutrient Broth: 10^{-5}: 3 +, 10^{-6}: 3 -

Anaerobic PCA

(1) 10^{-3} 22 Bacillus

(2) 10^{-4} 76

(3) 10^{-2} 9

(4) 10^{-2} 63

Aerobic PCA

		(a)	(b)
(3)	10^{-2}	13 + 1 mold 5 bright yellow 1 pale yellow	15 + 3 molds 6 deep yellow 5 pale yellow
(4)	10^{-2}	47, 70	yeast

BA (3) $10^{-1.3}$ 6(?) Strep
19 Deep yellow colonies
? Corynebacterium, Molds
Few Bacillus and cocci
102 Total

MacC $10^{-1.3}$ 16 Red

VRB $10^{-1.3}$ 17 Red

MSA $10^{-1.3}$ 5 Staph

MS $10^{-1.3}$ 6 Black colonies

BA 10^{-4} 89 ? Yeast

MAC $10^{-1.3}$ No growth

VRB $10^{-1.3}$ No growth

MS $10^{-1.3}$ No growth

MSA Same organisms as B.A. + PCA

3-1 Mod. Flat shining - bright yellow colonies

PCA, BA Gram Stain very small gm(-) rods

Some on MSA

3-2 Slightly larger than above - pale yellow colonies

PCA, BA Gram Stain very small gm(-) rods

Some on MSA NAS

3-3 Enterococcus - Like colonies - slightly green

BA Gram Stain Streptococcus

3-4 Pink colonies Lactos Broth

3-5 VRB

3-6 Pink colonies Lactose Broth/ MacConkey

3-7 Pink colonies Lactose Broth/MacConkey

3-8 Pink Colonies Lactose Broth/MacConkey

3-9 Black Colonies MS NAS

4-1 Yeast like colonies on: PCA, BA, MSA, CRB ·

GM Stain Budding Yeast

NAS

July 28, 1970

Lactose Broth 3-4 through 3-8 all negative

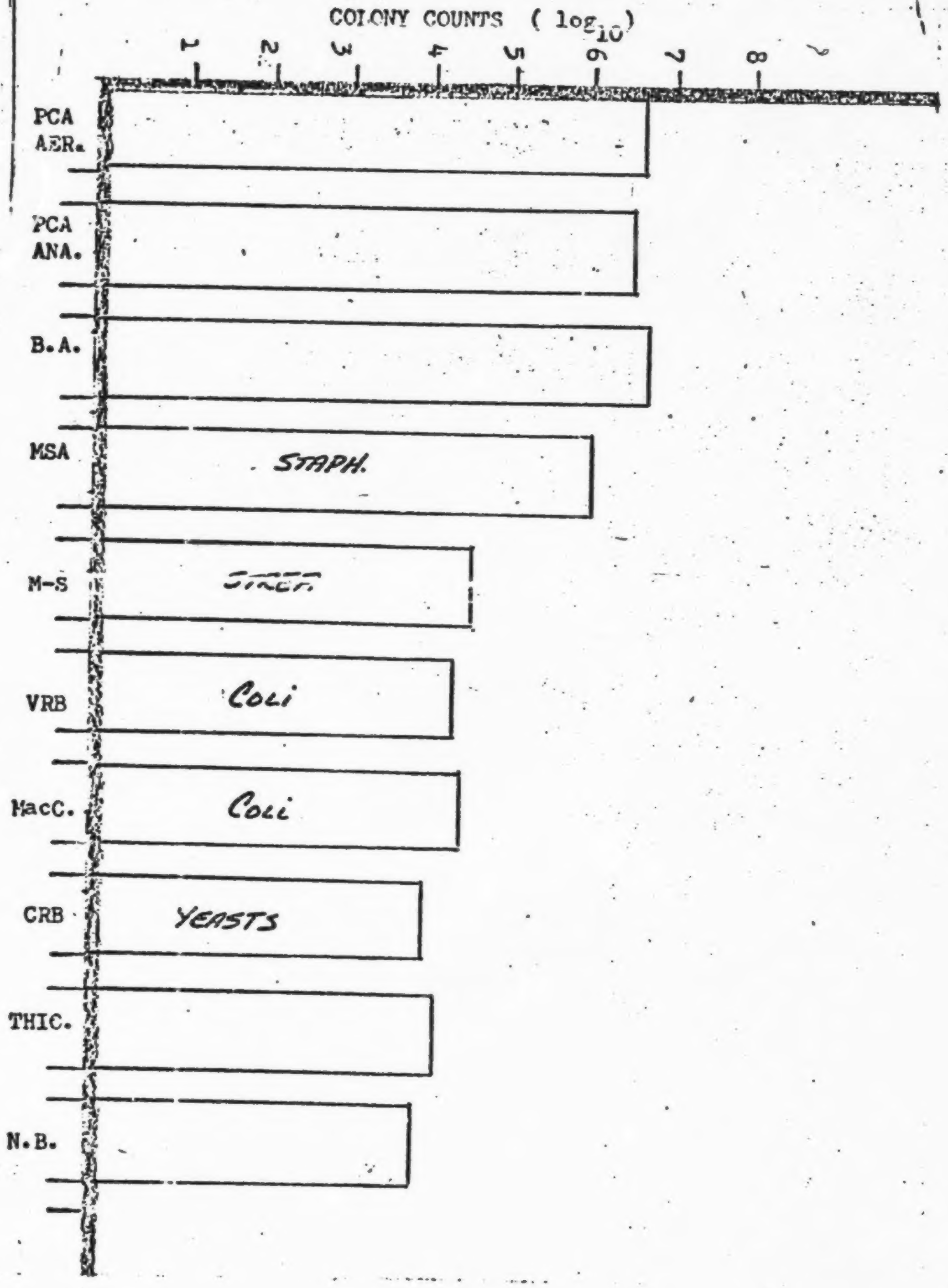

Figure C-1

HISTOGRAM FOR BACTERIAL COUNTS TEST 0

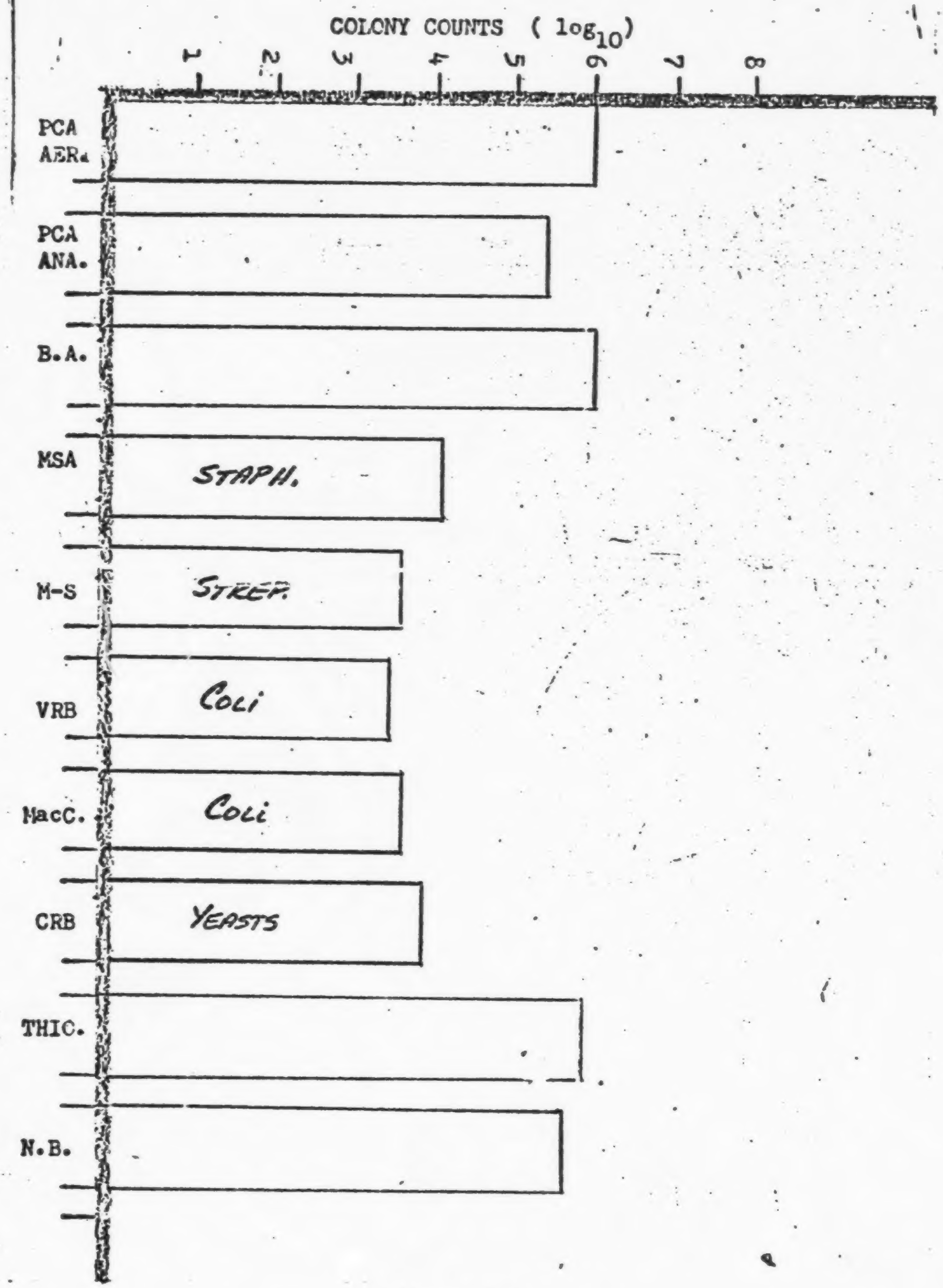

Figure C-2

HISTOGRAM FOR BACTERIAL COUNTS TEST 1

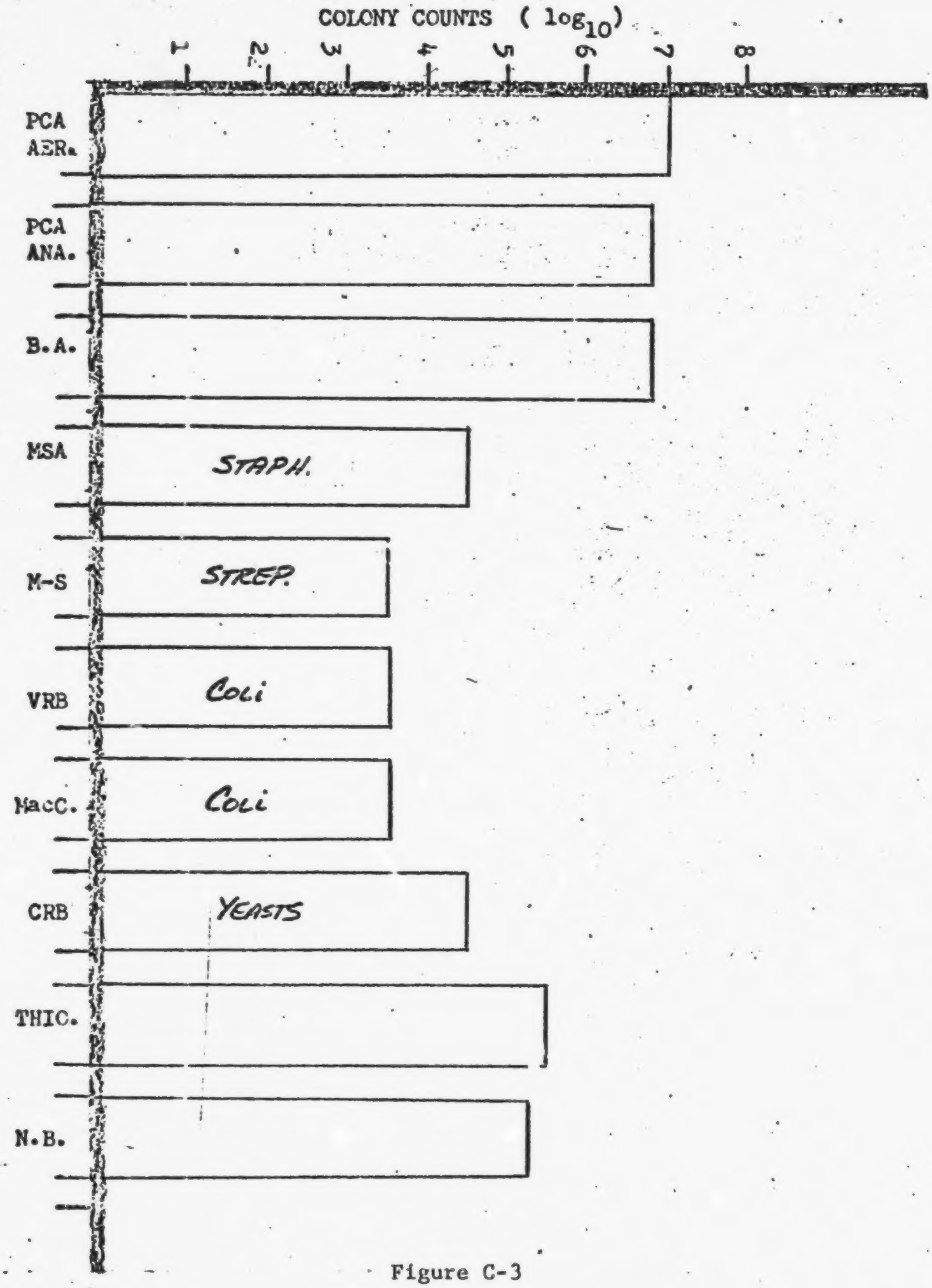

Figure C-3

HISTOGRAM FOR BACTERIAL COUNTS TEST 2

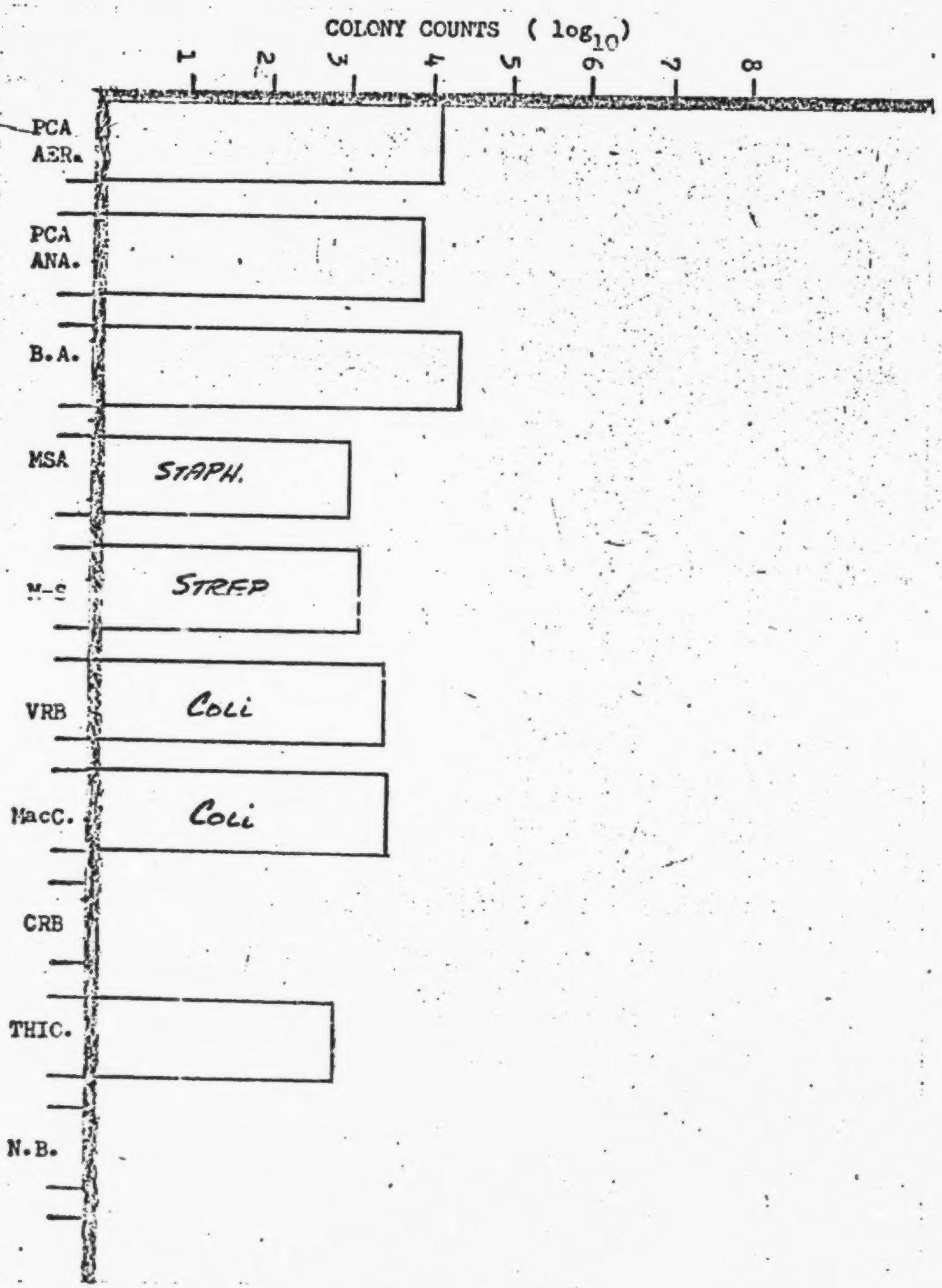

Figure C-4

HISTOGRAM FOR BACTERIAL COUNTS TEST 3

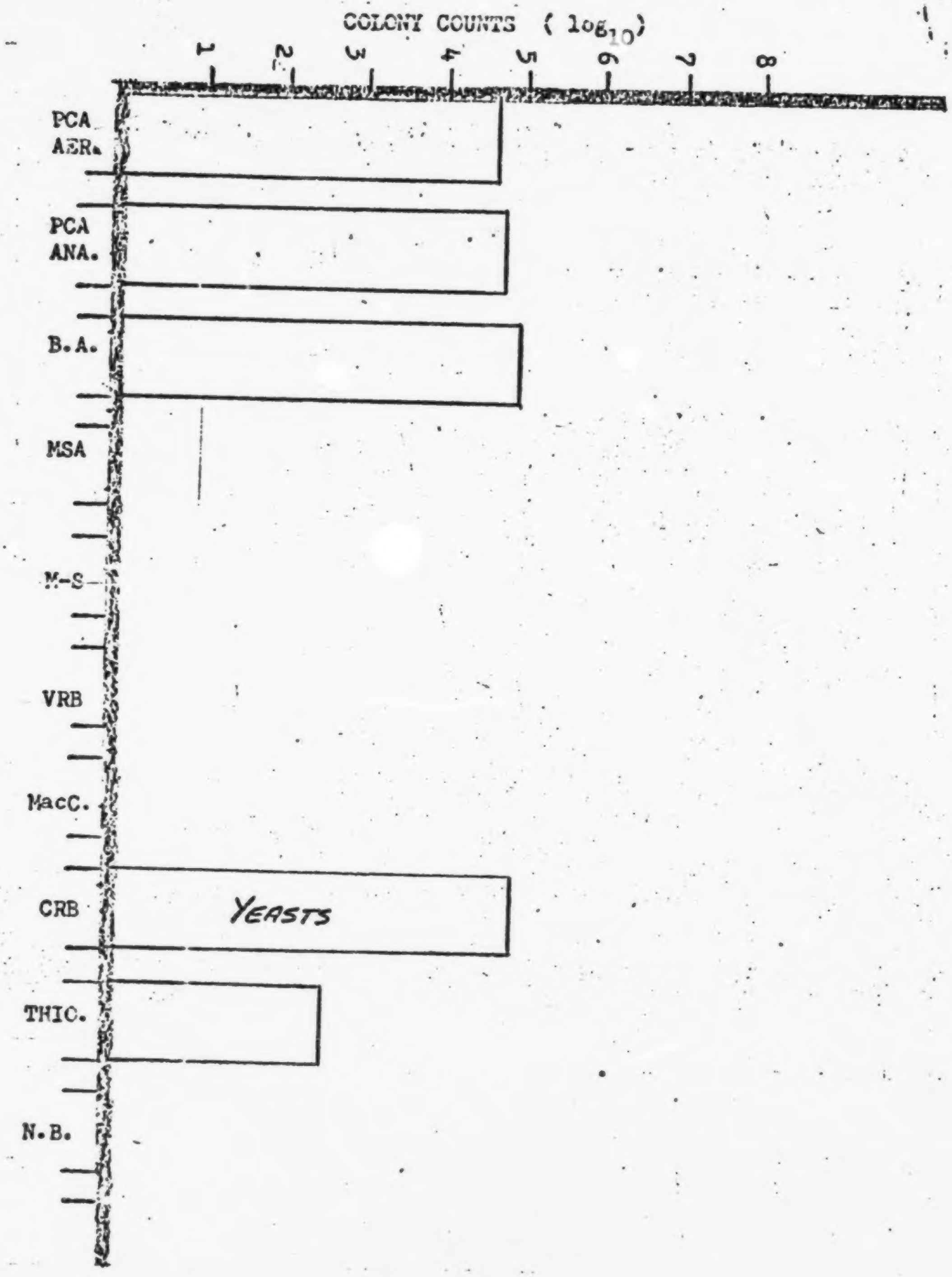

Figure C-5

HISTOGRAM FOR BACTERIAL COUNTS TEST 4

Brewer Anaerobic Jar
Baltimore Biological Laboratory, Inc.
Division of Becton, Dickinson and Company

Use with Hydrogen

Hydrogen is an explosive gas and all precautions must be taken to avoid laboratory accidents.

1. After closing and sealing with suitable material, the jar is attached to the source of hydrogen by means of a rubber tube.

2. The hydrogen is admitted at a pressure of 1 to 2 pounds per square inch. No preliminary evacuation is necessary.

3. Using the cord furnished, connection is made directly to 110-volt AC or DC current.

4. Maintain the hydrogen supply and the electrical connection for a period of thirty (30) minutes.

5. Pull out electric plug, tighten clamp on rubber tubing, disconnect it, and place the jar in the incubator.

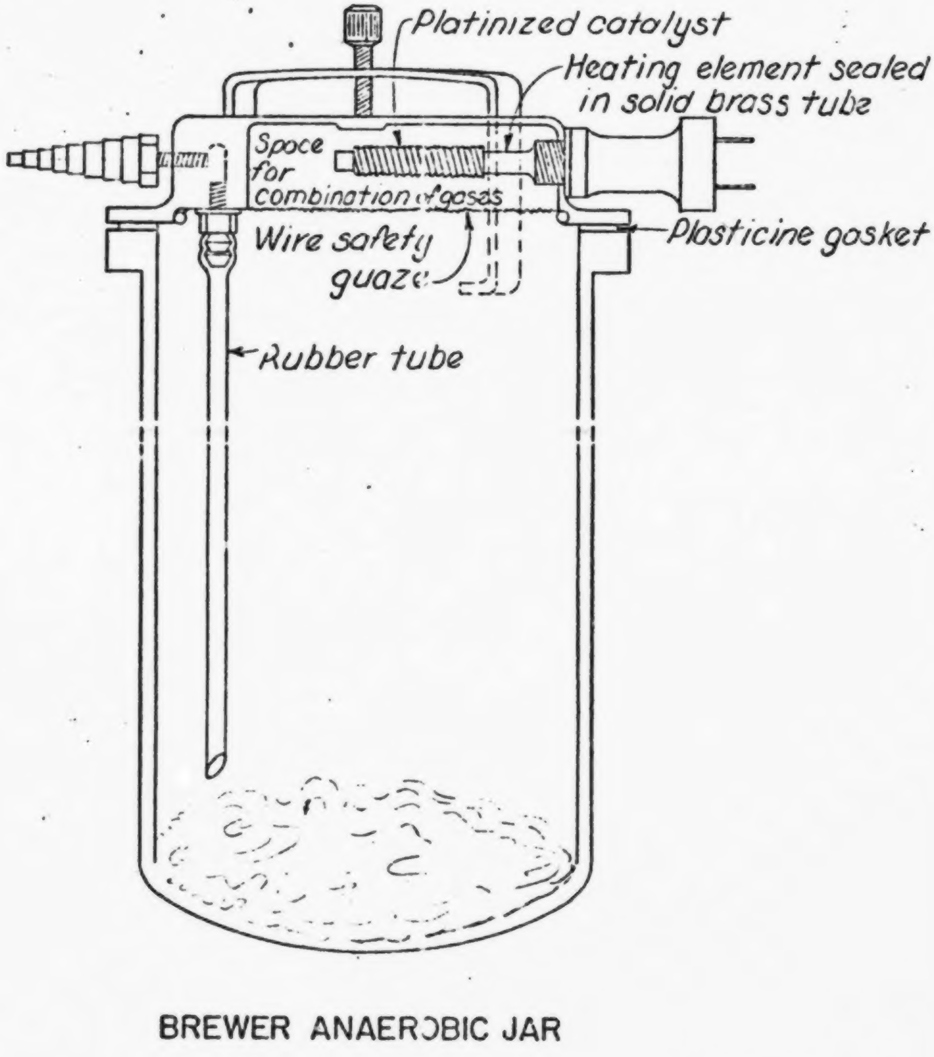
Platinized catalyst
Heating element sealed in solid brass tube
Space for combination of gases
Wire safety guaze
Plasticine gasket
Rubber tube
BREWER ANAEROBIC JAR

Figure C-6 Brewer Anaerobic Jar

Table C-1

Hospital Stations and Sampling Dates

Station Number	Sample Number	Date of Sample	Function of Station	Location of Station
11	1	10/5/70	Emergency Rooms	1st Floor
	2	10/14/70		
	3	10/19/70		
12	1	11/16/70	Outpatient Clinics	1st Floor
	2	1/18/71		
	3	1/25/71		
31	1	10/19/70	Orthopedics, Neurosurgery	3rd Floor
	2	10/21/70		
	3	10/28/70		
32	1	9/30/70	Orthopedics	3rd Floor
	2	10/26/70		
	3	11/9/70		
33	1	9/30/70	Intensive Care Unit, Recovery	3rd Floor
	2	11/2/70		
	3	2/8/71		
36	1	10/5/70	Operating Rooms	3rd Floor
	2	11/11/70		
	3	12/9/70		

Table C-1 (Continued)

Station Number	Sample Number	Date of Sample	Function of Station	Location of Station
41	1	11/16/70	Maternity	4th Floor
	2	11/18/70		
	3	12/2/70		
51	1	10/14/70	Surgery, Cardio Vascular Care, Urology, Eye, Chest, Burn Care	5th Floor
	2	10/21/70		
	3	11/4/70		
52	1	10/7/70	General Surgery	5th Floor
	2	11/18/70		
	3	12/9/70		
61	1	10/12/70	Gynecology, Neurology, Ears, Nose, and Throat	6th Floor
	2	11/4/70		
	3	12/7/70		
62	1	12/2/70	Pediatrics	6th Floor
	2	12/7/70		
	3	1/12/71		
71	1	11/9/70	General Medicine	7th Floor
	2	11/11/70		
	3	1/28/71		

Table C-1 (Continued)

Station Number	Sample Number	Date of Sample	Function of Station	Location of Station
72	1	10/7/70	General Medicine	7th Floor
	2	1/21/71		
	3	1/28/71		
82	1	10/26/70	Psychiatric Care	8th Floor
	2	10/28/70		
	3	11/2/ 70		
83	1	10/12/70	Metabolic Care	8th Floor
	2	1/21/71		
	3	1/25/71		

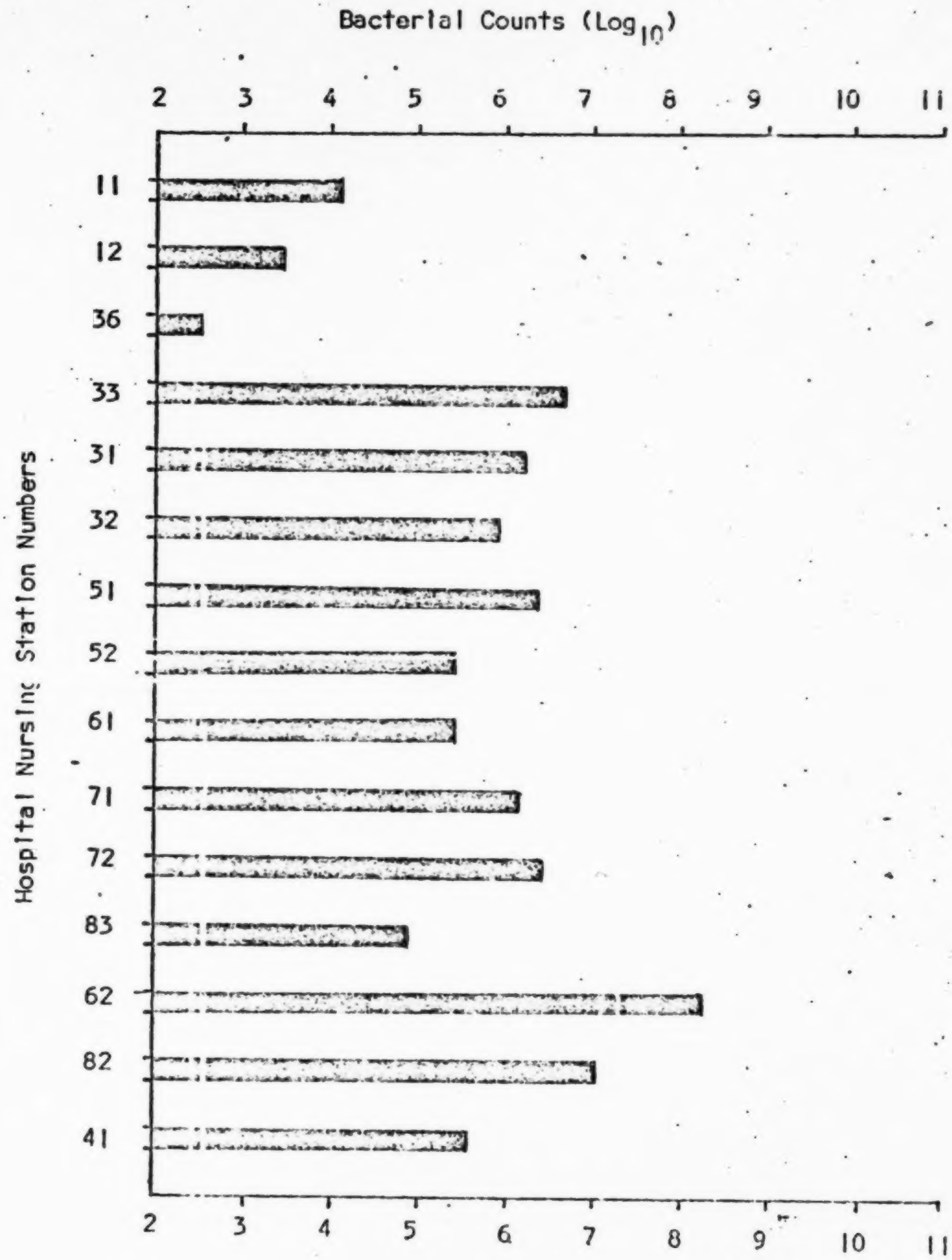

Figure C-7 Comparison Of The Total Microbial Counts For 15 Nursing Stations

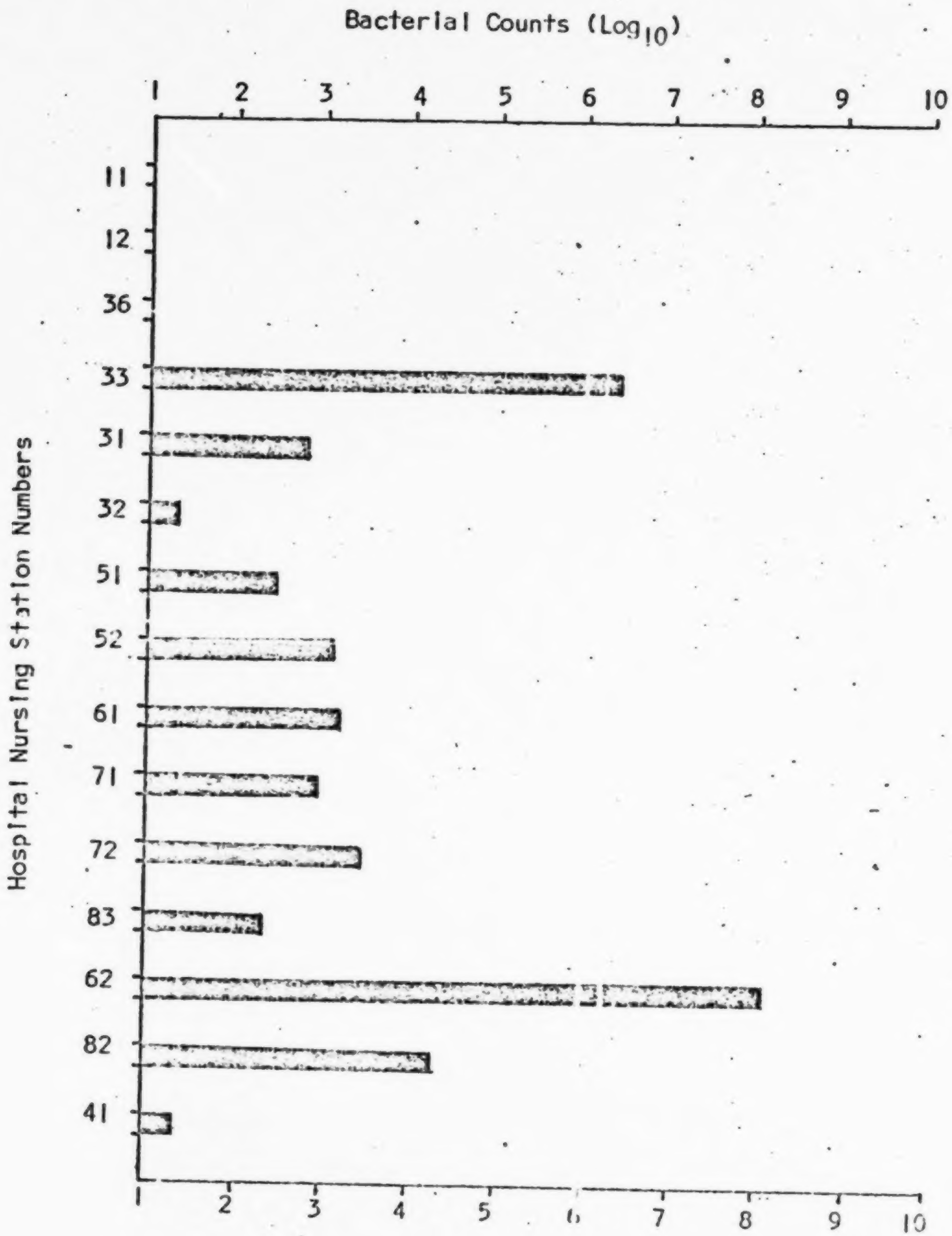

Figure C-8 Comparison Of The Group I Bacterial Counts For 15 Nursing Stations

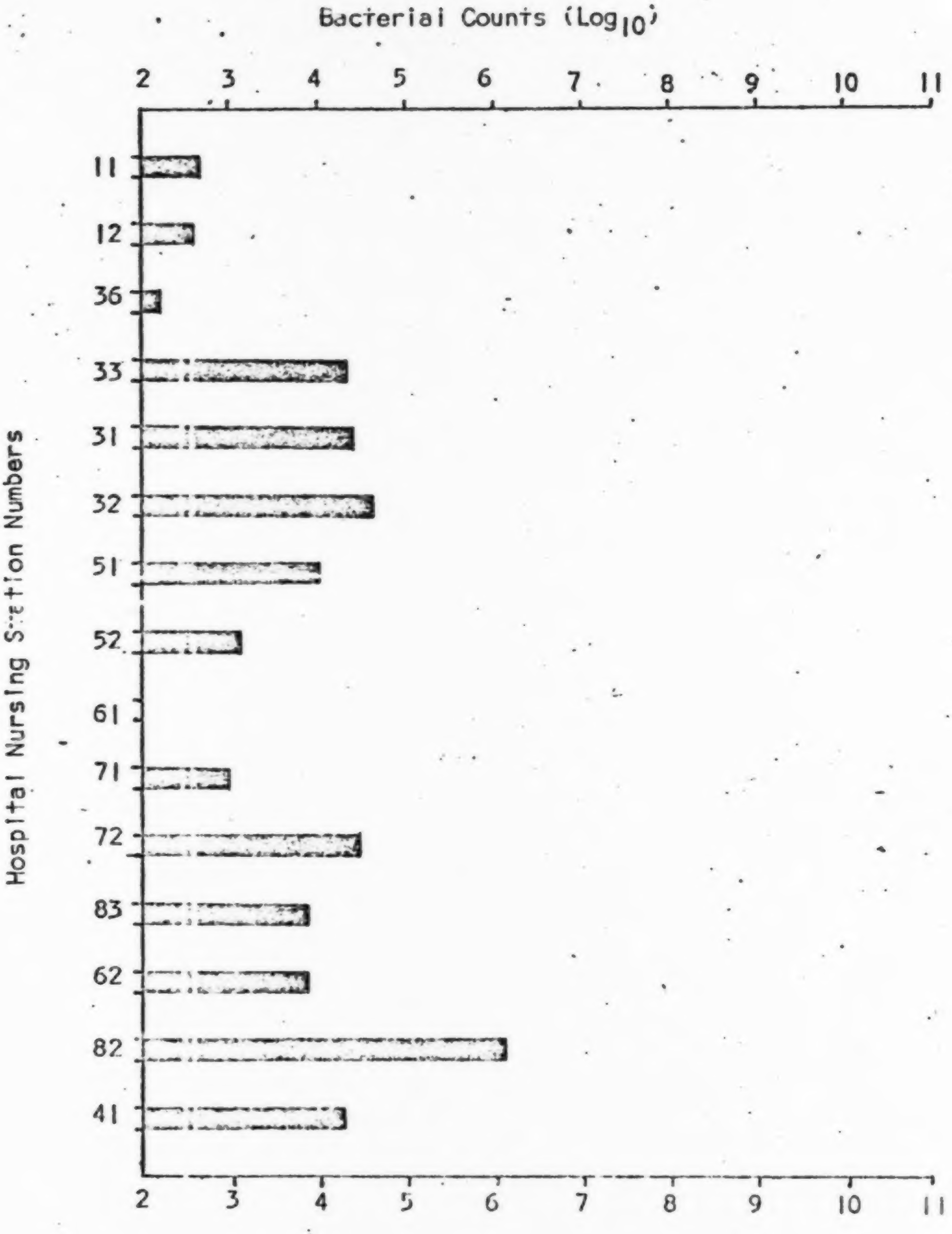

Figure C-9 Comparison Of The Group II Bacterial Counts For 15 Nursing Stations

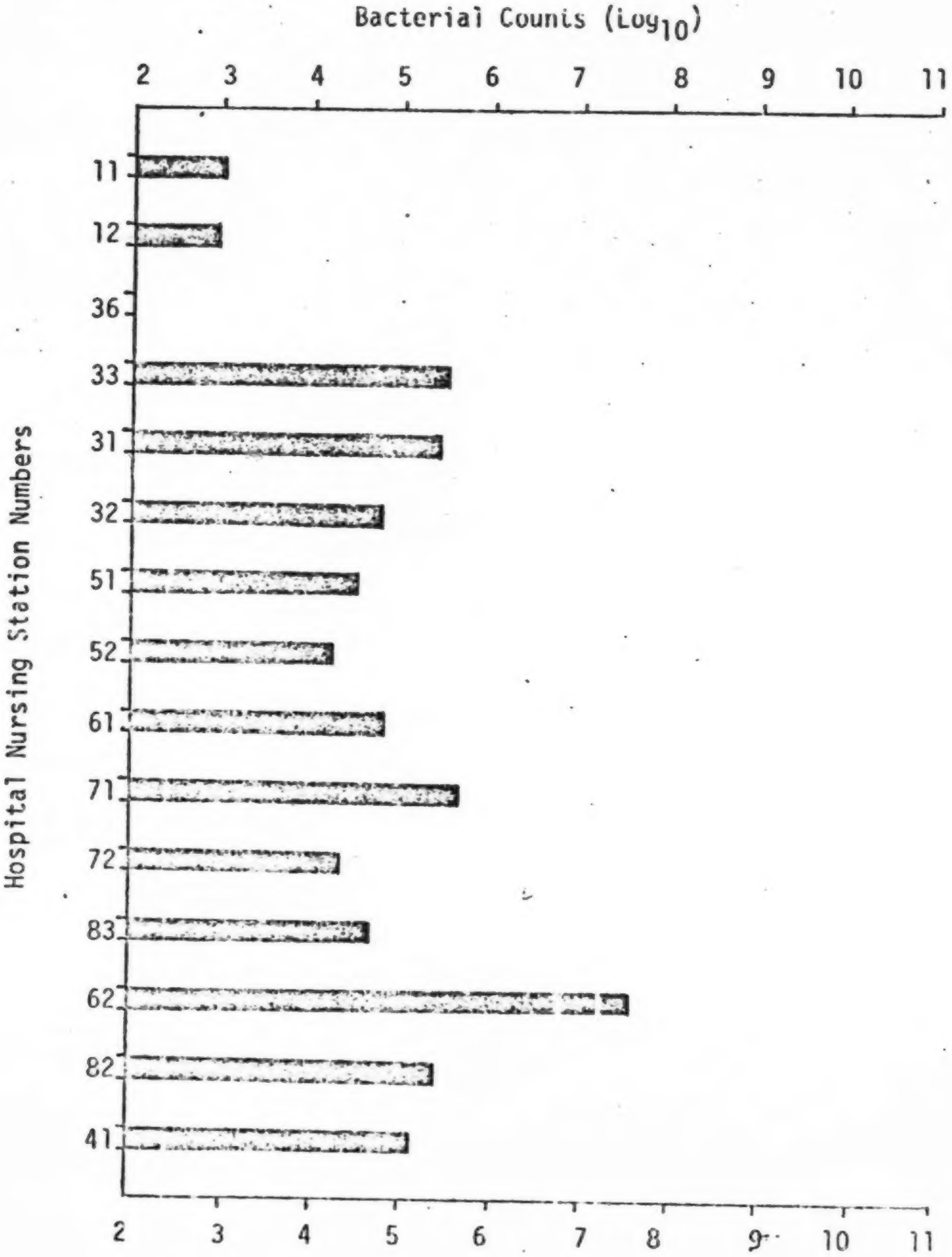

Figure C-10 Comparison Of The Group III Bacterial Counts For 15 Nursing Stations.

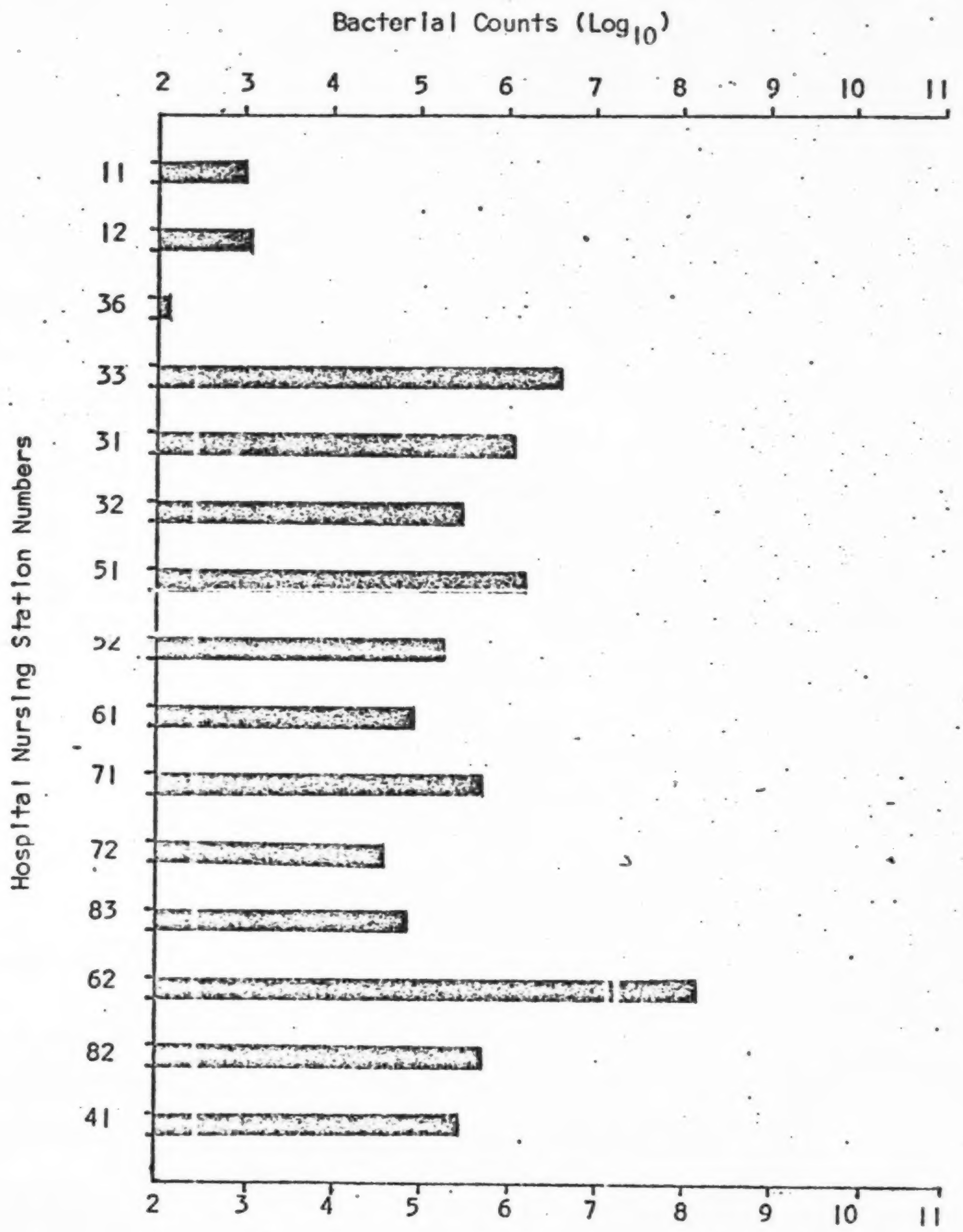

Figure C-11 Comparison Of The Group IV Bacterial Counts For 15 Nursing Stations

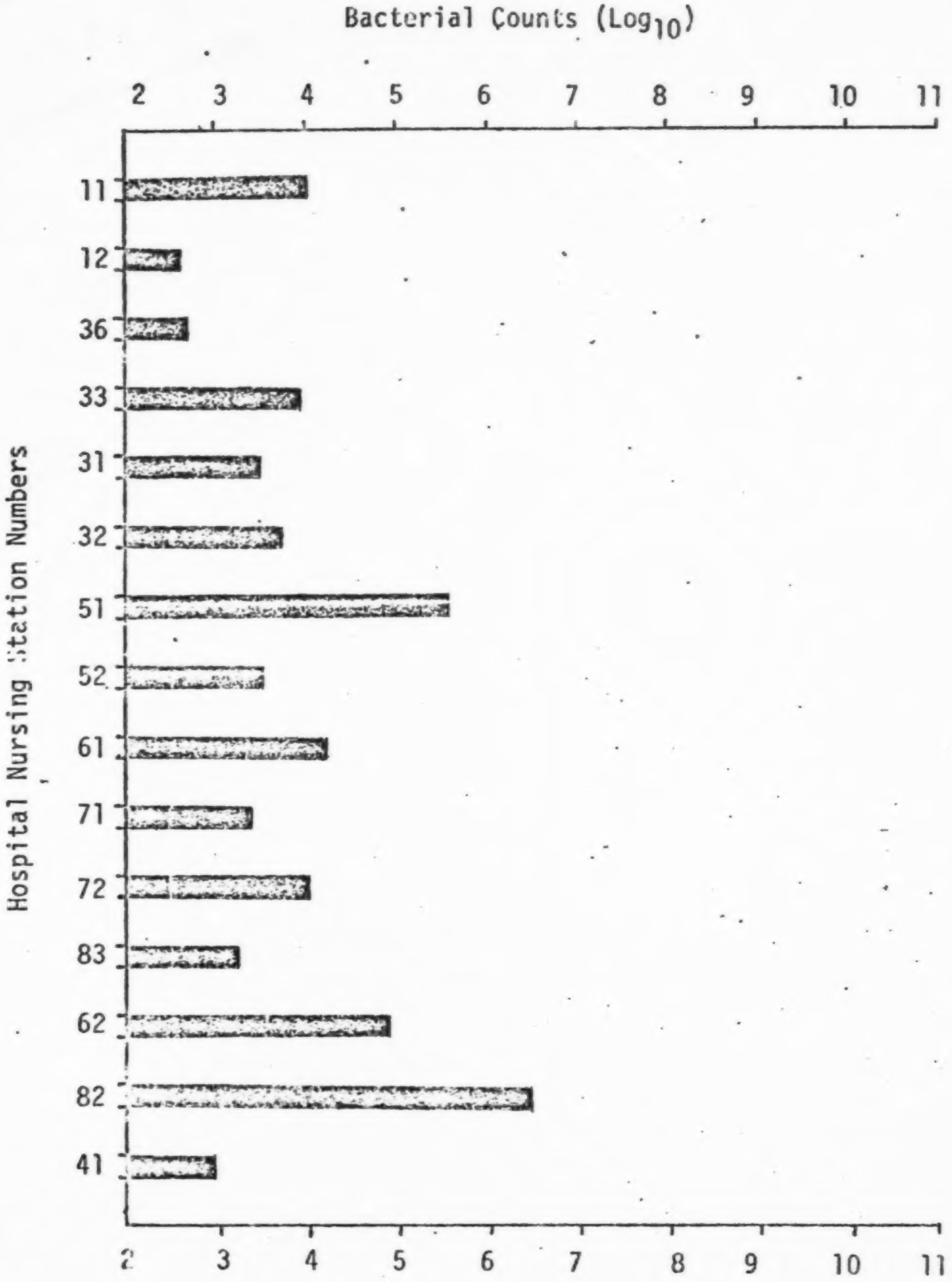

Figure C-12 Comparison Of The Group V Bacterial Counts For 15 Nursing Stations